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A Stereotaxic Atlas of the Squirrel Monkey's Brain

(Saimiri sciureus)

Gift 5/15/85

A Stereotaxic Atlas of the

SQUIRREL MONKEY'S BRAIN

(*Saimiri sciureus*)

by

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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Foreword

Dr. Paul D. MacLean began working with the squirrel monkey (Saimiri sciureus) in the Fulton laboratory at Yale in 1950, and introduced it into the NIMH laboratary in 1957. It has been an inspiration to observe the work he and his collaborators have done in the succeeding years. The squirrel monkey was first used in the United States by Heinrich Klüver. This gentle little primate from the South has continued to have increasing value for laboratory study. It is a small animal with a relatively large brain and a highly organized nervous system. It is quiet, trainable and adapts well to both acute and chronic experimentation. Large numbers can be contentedly maintained in a relatively small space. Resistance to infections, including tuberculosis, is high.

Drs. Gergen and MacLean have produced this Horsley-Clarke type of atlas with meticulous care. It includes the whole hemispheres, and great effort has been expended to show the degree of scatter to be expected. This atlas will be of great service to brain research.

Bethesda, Maryland

WADE H. MARSHALL, *Chief,*
Laboratory of Neurophysiology

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Introduction

In our experience the squirrel monkey (*Saimiri sciureus,* Voigt, 1831) has proved to be an excellent experimental animal for many kinds of brain and behavioral work for which a primate form is desired (1, 4, 5, 6). Unlike the larger primates, this New World monkey has the advantage that its brain, which is comparable to the cat's in weight and size, is of desirable dimensions for combined neurophysiological and neuroanatomical investigations. There is the added advantage that its small body makes it easy to handle and economical to maintain. Representative measurements of its body and brain are given in table I. Some details in regard to the purchase and maintenance of the squirrel monkey are discussed in the appendix.

TABLE I—REPRESENTATIVE BODY AND BRAIN MEASUREMENTS OF THE SQUIRREL MONKEY*

	Number of animals	Mean	Standard deviation
Weight	76	717 g	±170. 4
Body length	49	260 mm	±24. 7
Tail length	50	360 mm	±21. 4
Total length	48	630 mm	±35. 7
Head length	45	54 mm	±2. 2
Head width	45	41 mm	±3. 6
Brain weight	21	26 g	±1. 7
Brain length	29	49 mm	±2. 1
Brain width	30	35 mm	±1. 7

* (From: Carmichael, M. and MacLean, P. D. *EEG Clin. Neurophysiol.*, 1961, *13:* 128–129.)

The squirrel monkey is indigenous of Central America and of extensive areas of northern South America. It belongs to the family Cebidae. The generic term Saimiri (which is assigned a masculine gender) is presumably an Indian term for this particular type of monkey.[1] Hill (2) gives an extensive taxonomical description of a number of species and subspecies, as well as some information about their territorial origin and general behavior. The Saimiri are arboreal animals characterized by an elongated oval head, a somewhat flat face with closely placed eyes, and a long, nonprehensile tail. The common squirrel monkey (Saimiri sciureus) has soft, orange-brown to grey colored fur which is of similar hue on the back and crown.

In answer to requests for stereotaxic data on the squirrel monkey, we have sent to several laboratories a duplicated line drawing atlas. Continuing requests for this material have encouraged us to proceed with a publication of the present photographic atlas.

[1] Personal communication from Dr. David H. Johnson, Curator of Mammals, United States National Museum.

Materials and Methods

Horsley-Clarke technique

A Horsley-Clarke apparatus used for the cat or macaque may be adapted with little or no modifications for experiments on the squirrel monkey. The horizontal reference plane of most instruments is based on lines passing through each orbitale and the centers of the external auditory meati (approximate Frankfort plane). As it is undesirable to cut the lower eyelid in chronically prepared animals, it is the practice of this laboratory to elevate the level of the eye piece to allow for the thickness of the eyelid. A photograph of the eye piece and its alinement with the straight ear bars of the Horsley-Clarke apparatus used in the present study is shown in figure 1. The triangular notch in the eye piece is 1.5 mm. deep and 3.0 mm. broad; the axial center of the ear bar is on a line with the lower surface of the eye piece. The ear bars are inserted directly into the external auditory meati; the final distance between tips after insertion usually measures 19–21 mm.

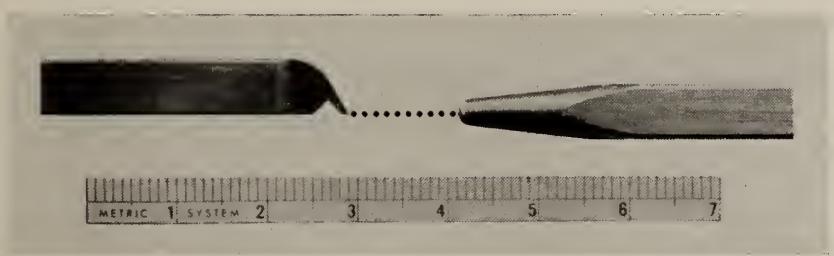


Figure 1—Notched eye piece and ear bar of Horsley-Clarke apparatus used in the present study. The dotted line connecting center of ear bar and lower surface of eye piece indicates the horizontal zero plane. The notch of eye piece allows for thickness of eyelid so that the orbitale lies approximately on this plane.

Animals

The brain of SM12 for the frontal series depicted in this atlas was chosen for illustration because it was most representative of average stereotaxic measurements obtained on 31 adult male animals. The mean body weight for these animals was 821 g. (standard deviation 127 g., extremes of 550 and 1,050 g.).

Procedure

Multiple marking bars were placed under anesthesia in the brain of each animal as a guide to sectioning and to determine the position of frontal and horizontal planes. In each case X-rays were obtained of the animal's head to check the alinement of bars and to confirm the distance between them. Figure 2 illustrates the lateral skull X-ray of animal SM12.

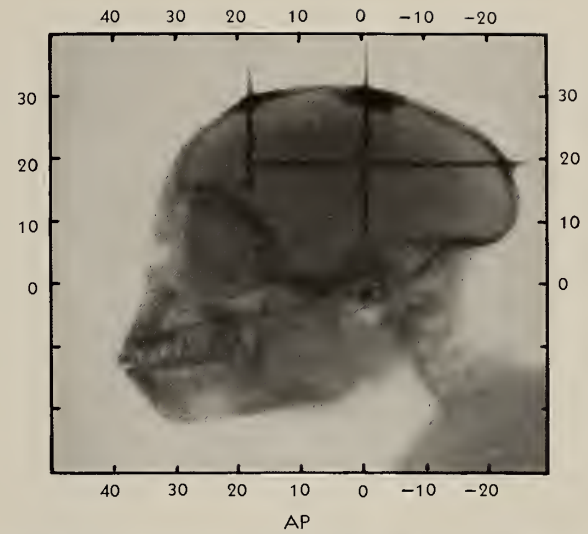


Figure 2—Lateral skull X-ray of monkey SM 12. The brain of this animal was used for making the frontal series of this atlas. Marker bars are present bilaterally at AP 18 and AP —0.5; a single horizontal bar falls at H 19.5. The opacity near the ear canal is part of the head holder.

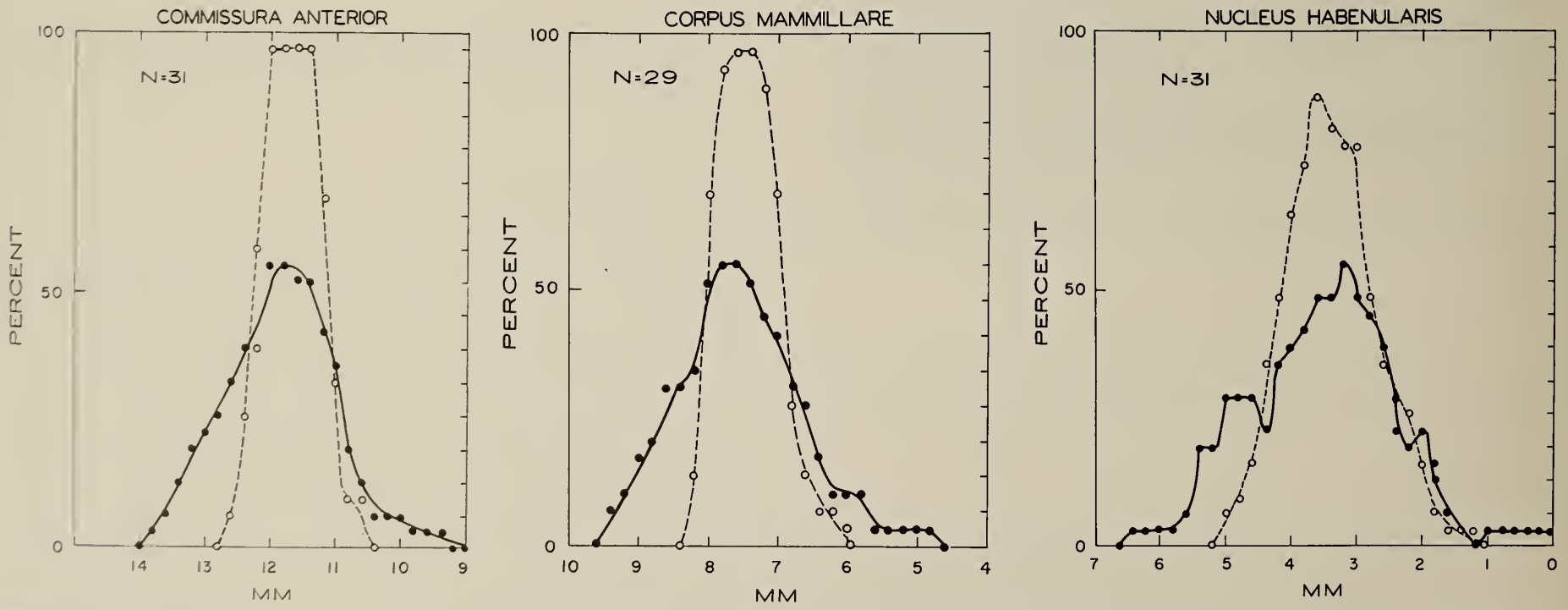
Histological techniques

At sacrifice all animals were perfused through the heart with 100–200 cc. of normal saline at 40° C., followed by an equal amount of a mixture of 10% formalin-1.0% agar agar (U.S.P.) at 40° C. The intact head was placed in the refrigerator overnight, and the brain was removed on the following day. The 2½–3½ cm. block to be sectioned was immersed in formalin-agar agar at 40° C. for several days; 24 hours before sectioning ethyl alcohol was added to a concentration of 20%. Serial frozen sections were prepared by the Marshall technique (7) with the microtome set at approximately 50μ and cutting in a dorsal to ventral direction. The final thickness of sections was calculated by dividing the number of sections into the distance between marking bars. Sections were saved at 0.5 mm. intervals and mounted on glass slides covered with egg albumen. Facing sections were respectively stained with cresyl violet and Lillie's variant of the Weil-Weigert method (3). To judge distortions inherent in fixation, cutting and mounting, dimensions of the sections were compared with measurements taken stereotaxically from the base of the animal's skull and from its skull X-ray. Twenty-nine brains were cut in the frontal plane and two in the sagittal plane.

Variability in Position of Cerebral Structures

To estimate the variation in position of brain structures that one might expect in routine experimental procedures, an analysis was made of the coordinates of the Commissura anterior, Corpus mammillare and Nucleus habenularis. Anterior and posterior limits of these structures for a parasagittal plane were estimated from the histological material on 31, 29, and 31 animals, respectively. The anterior-posterior extent of each of these structures is plotted in a cumulative profile by the solid lines in figures 3, 4, and 5. Each of these structures typically has a maximal extent of 1–1.5 mm.; the rising slope of the solid line curves in these figures thus largely represents the anterior limits for each structure while the falling slope reflects the posterior boundary.

The data suggest that there is about a 50% chance of encountering one of these structures at its optimal stereotaxic coordinates. The variation between extremes for any one point in one of the structures exceeds 4 mm. in AP coordinates; however, 90% of the animals show a variation of 1.5 mm. or less from the average. The dotted lines represent the curves obtained after displacing all structures in any one animal by a constant distance in the anterior-posterior direction. This displacement was arbitrarily chosen to bring the coordinates of all of these structures for each animal close to the population mean. For different animals, the displacement chosen varied from +2.0 to −1.5 mm. These curves demonstrate that there is less variation in the relative position of these structures within the brain than that seen for the population.



Figures 3–5—In these figures the solid lines represent distribution profiles of the anterior-posterior extent of the Commissura anterior (CoA), Corpus mammillare (M), and the Nucleus habenularis (Ha) in 31, 29, and 31 animals, respectively, as found in routine stereotaxic procedures. Dotted lines in these figures represent a replotting of these distribution profiles after adding on arbitrary "displacement" to all the coordinate values of each animal (see text).

After establishing a displacement distance, an additional correlation could be shown between this distance and the animal's weight.[2] This correlation suggested that there is a tendency for brain structures to be posterior to the average in animals which have a body weight less than the mean, whereas the opposite tendency is present in animals in which the body weight is greater than the mean.

Differences among animals in the position and size of the external auditory meati are apparently a major cause of the stereotaxic variabilities that have been described. This conclusion is based on measurements in which other cranial loci were used to obtain reference planes. Table II lists useful landmarks which can readily be determined by X-ray examination.

TABLE II—AVERAGE STEREOTAXIC COORDINATES OF CALVARIAL STRUCTURES

Structure	Anterior-posterior	Horizontal
	Millimeters	*Millimeters*
Anterior limit of cranial vault	29±2	17±1
Orbital roof	20	14. 5±0. 5
Floor, olfactory groove	20	10. 5±0. 5
Floor, temporal fossa	9±2	0. 5±0. 5
Anterior edge of posterior clinoid process	8. 5±0. 5	5. 5±1. 0
Dorsal limit of cranial vault	5±2	31±2
Posterior limit of cranial vault	—22±2	15±2

A good approximation to the horizontal zero plane is provided by a line passing through the orbitale and just below the floor of the temporal fossa. The rostral boundary of the posterior clinoid processes falls at 8.5±0.5 mm. anterior to the ear canal (AP 0) of the average animal, while at 20 mm. anterior, the floor of the olfactory groove and orbital roof should lie at 10.5±0.5 mm. and 14.5±0.5 mm. above the horizontal zero. Figure 6 is a scatter diagram for 8 animals in which these skull landmarks were used to establish a stereotaxic frame of reference independent of the ear canals. Animals selected for this drawing included those with a wide deviation from the mean body weight. For comparison, the coordinates of SM12 are indicated by the heavier lines and the cross hatching. Connecting lines have been drawn through the centers of the structures of each animal to show angular relationships and the relative positions of these structures for any one animal. The range of scatter in this figure for the Corpus mammillare (M) and Commissura anterior (CoA) is approximately 1.5 mm. and is thus less than one half that shown in figure 3–4. The fact that coordinates for the Nucleus habenularis (Ha) show a wider scatter than the other structures suggests that cerebral distortion attributable to embryological development of the mesencephalic flexure contributes to a greater variation in the position of dorsocaudal thalamic structures than of those lying more rostral and ventral.

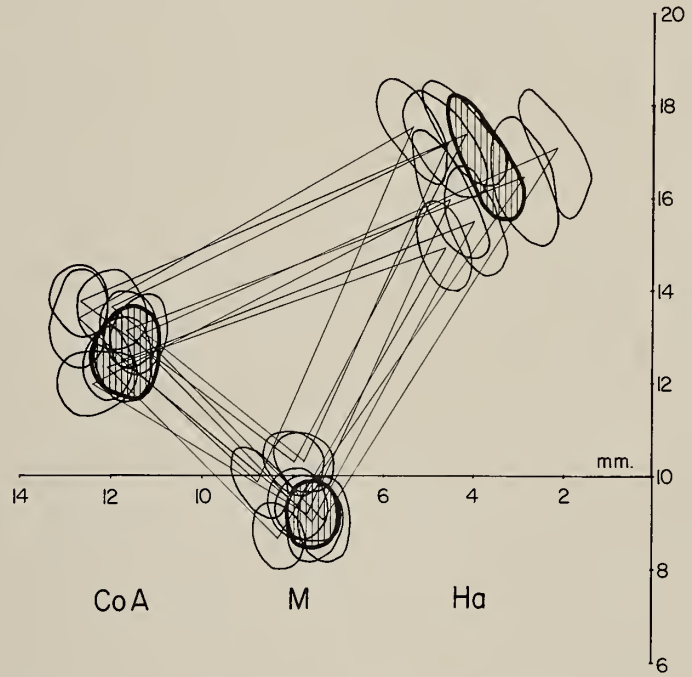


Figure 6—Scatter diagram of the parasagittal location of the Commissura anterior (CoA), Corpus mammillare (M), and Nucleus habenularis (Ha) in 8 animals in which the stereotaxic reference planes were determined by lateral skull X-ray without reference to the position of the ear canals (see table II and text). The cross-hatched areas show in addition the position of these structures in animal SM 12 used for the atlas. Lines are drawn between the approximate centers of these structures for each animal.

In summary, the findings indicate that in carrying out stereotaxic exploration under routine experimental conditions one would have a 50% chance of coming within 0.5 mm. of a point described by the coordinates of the present atlas. There would be a 90% chance of falling within 1.5 mm. of this target. In experiments in which a higher degree of accuracy is required it would be desirable to obtain appropriate X-ray data and to avoid the use of unusually large or small animals. In our experience the degree of accuracy that can be achieved in stereotaxic work in the squirrel monkey compares to that in the cat, and is significantly better than in the macaque.

[2] For the 29 animals with complete measurements on the position of all three structures, the regression line determined by the equation

"displacement" (mm) = 2.75 − 3.41 × weight (kg)

is significant (0.01 confidence level, T=3.47 with 27 degrees of freedom). Weight variations, however, in any one animal in our laboratory may be as much as 200 gms.; it should also be noted that after assuming this weight correction, displacements greater than 0.5 mm. would still be needed in 12 (41%) animals to obtain the dotted curves in figures 3–5.

Acknowledgments

Many people have contributed to the preparation of this atlas. Miss Martha Carmichael and Mr. George Creswell assisted in preparing the histological material and proofread the plates and tables. Dr. Kent D. Morest and Dr. William H. Mehler generously consulted with us in regard to the dorsal tegmentum and optic thalamus, respectively. Miss Norma Beck typed the manuscript. Mr. Levi Waters was responsible for the care of the animals.

The photography was done in the Medical Arts and Photography Branch of the National Institutes of Health under the supervision of Mr. Roy Perry and Mr. Vernon E. Taylor. Mr. Paul Ellis photographed the slides and helped in solving problems pertaining to the grid used on the frontal sections. Mr. Ralph Fernandes enlarged and developed the prints.

We wish to express our appreciation to Dr. Wade H. Marshall of the Laboratory of Neurophysiology, National Institute of Mental Health, for his help in seeing this atlas through to publication.

Finally, we wish to acknowledge our great indebtedness to the Government Printing Office for the special care given to its production.

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Explanation of Plates

Reference Planes

The horizontal zero plane (H 0) for this atlas is defined as the plane passing along the inferior flat surfaces of the eyepieces through the center of the ear bars (see Methods). All brain structures anterior to the medulla oblongata lie above this plane. The frontal zero plane (AP 0) is defined as the plane which passes through the center of the ear bars and is perpendicular to the horizontal zero plane. The lateral zero plane is defined as perpendicular to the horizontal and frontal zero planes and passing midway between the two ear bars in their final position. The sagittal suture usually lies within 1 mm. of the lateral zero plane; best reliability is obtained by exposing and utilizing the superior sagittal sinus.

Frontal Series

In the plates for the frontal sections (SM12), AP designations represent the plane for which the section is considered representative. Positive AP numbers refer to distances in millimeters anterior to AP 0. Deviations between the desired and actual positions of any section are no more than 0.2 mm.; the calculated position of each section is given in smaller type. The grid overlying one-half of the frontal section is scored in millimeter intervals. Numbers along the sides of each plate represent 5 mm. intervals in the lateral and horizontal planes.

Sagittal Series

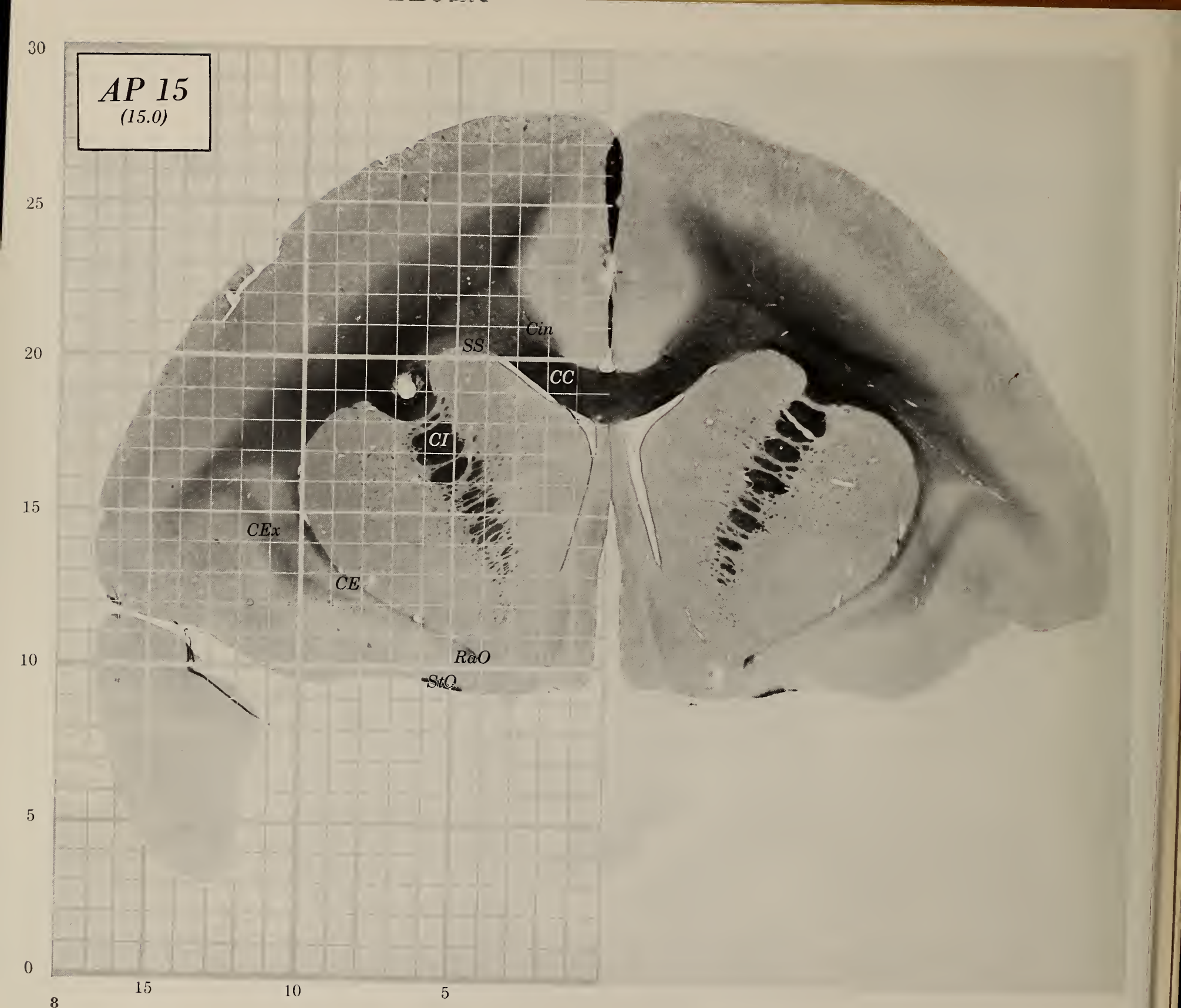
Following the frontal series are plates showing representative sagittal sections stained by the Weil-Weigert method. These are presented to indicate the relative position of brain structures anterior and posterior to those in the frontal series and to facilitate visualization of spatial relationships. These plates are alphabetically identified. The approximate distance of the section from the midline appears beneath the letter. The abbreviations are listed in tables III and IV.

Nomenclature

The terminology of this atlas is based on that compiled by Riley in his remarkable and recently republished "An Atlas of the Basal Ganglia, Brain Stem and Spinal Cord" (9). In 15 instances terms have been taken from other references; these are indicated by an asterisk in tables III and IV.

Labeling and Abbreviations

Structures which are comprised largely of white matter are labeled in italics on the plates showing sections stained by the Weil-Weigert method; principal cellular groups are identified by Roman letters on the plates showing the Nissl-stained sections. The corresponding abbreviations are given in tables III and IV. Initials for generic terms (e.g., nucleus) are not used except for the following: brachium, capsula, commissura, lemniscus, pedunculus, radiatio, stria and stratum. In these instances cross-references are given.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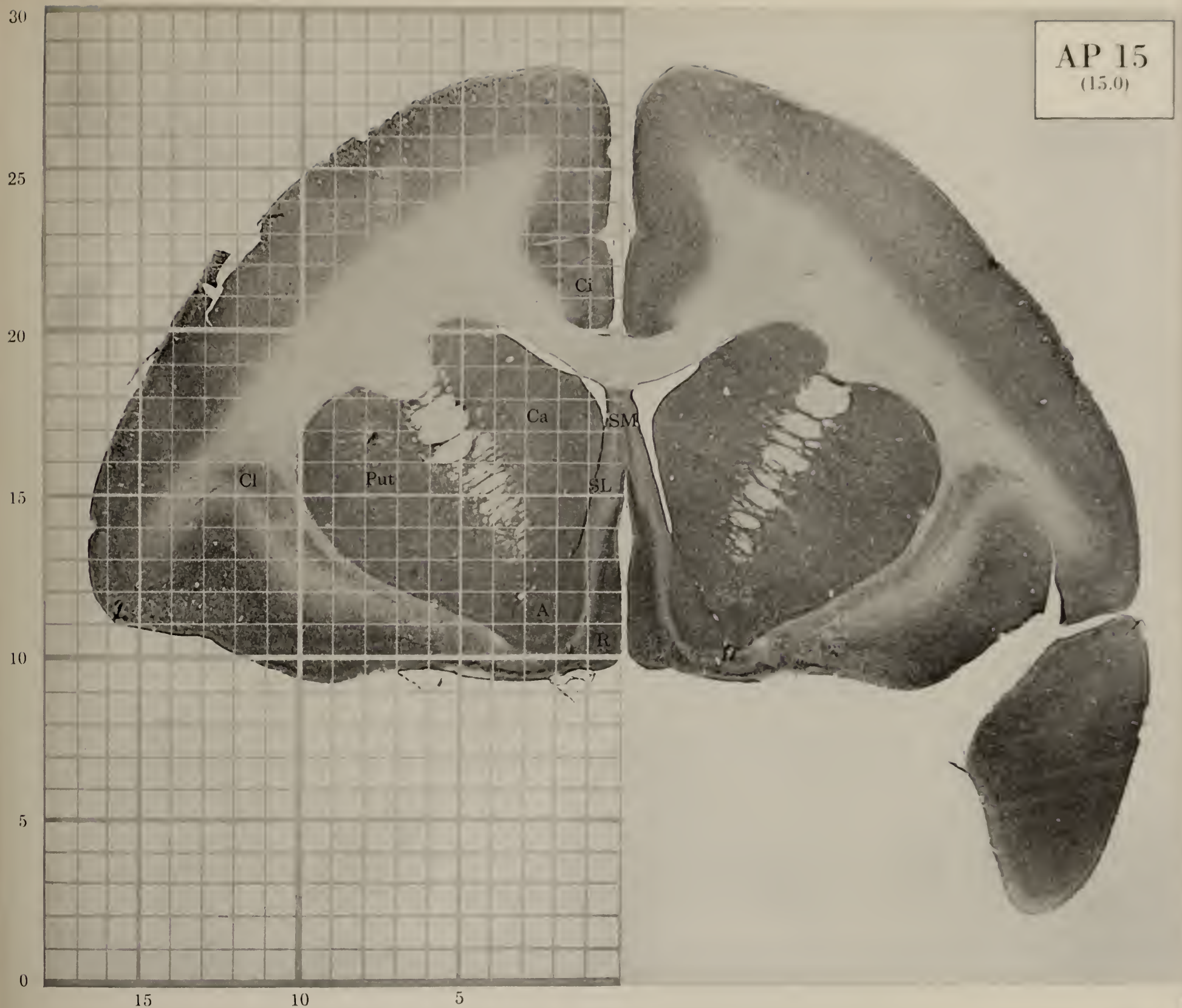
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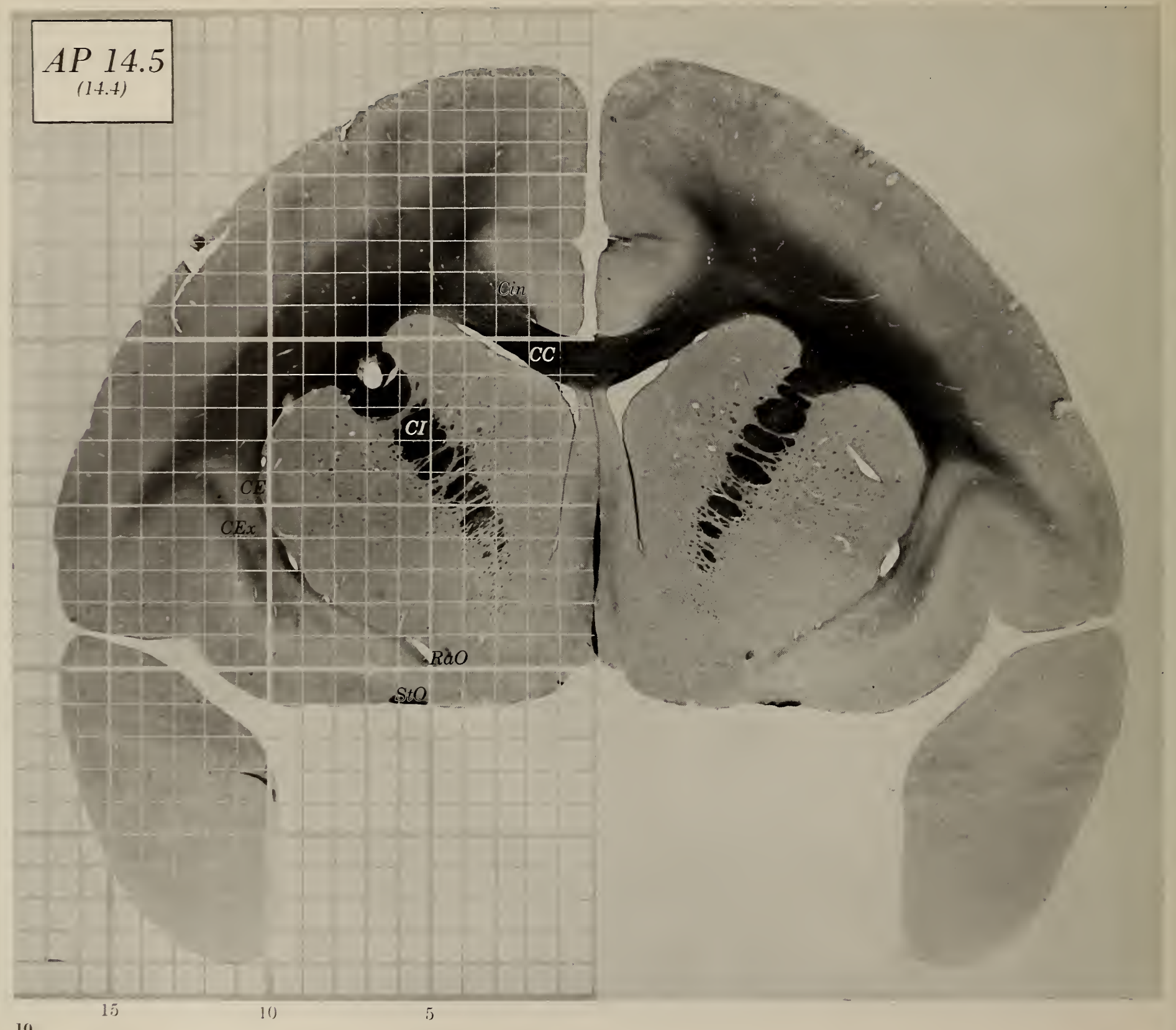
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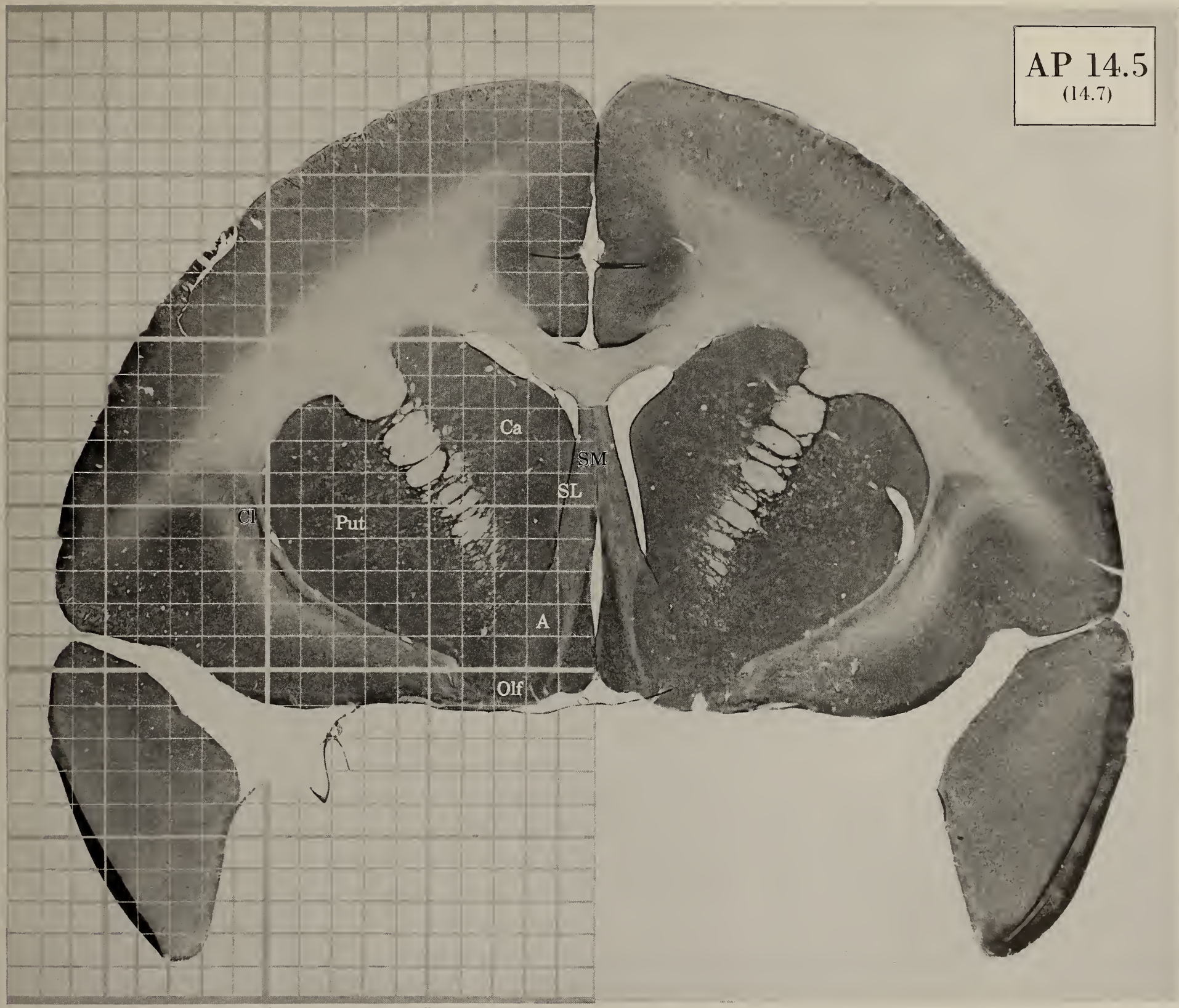
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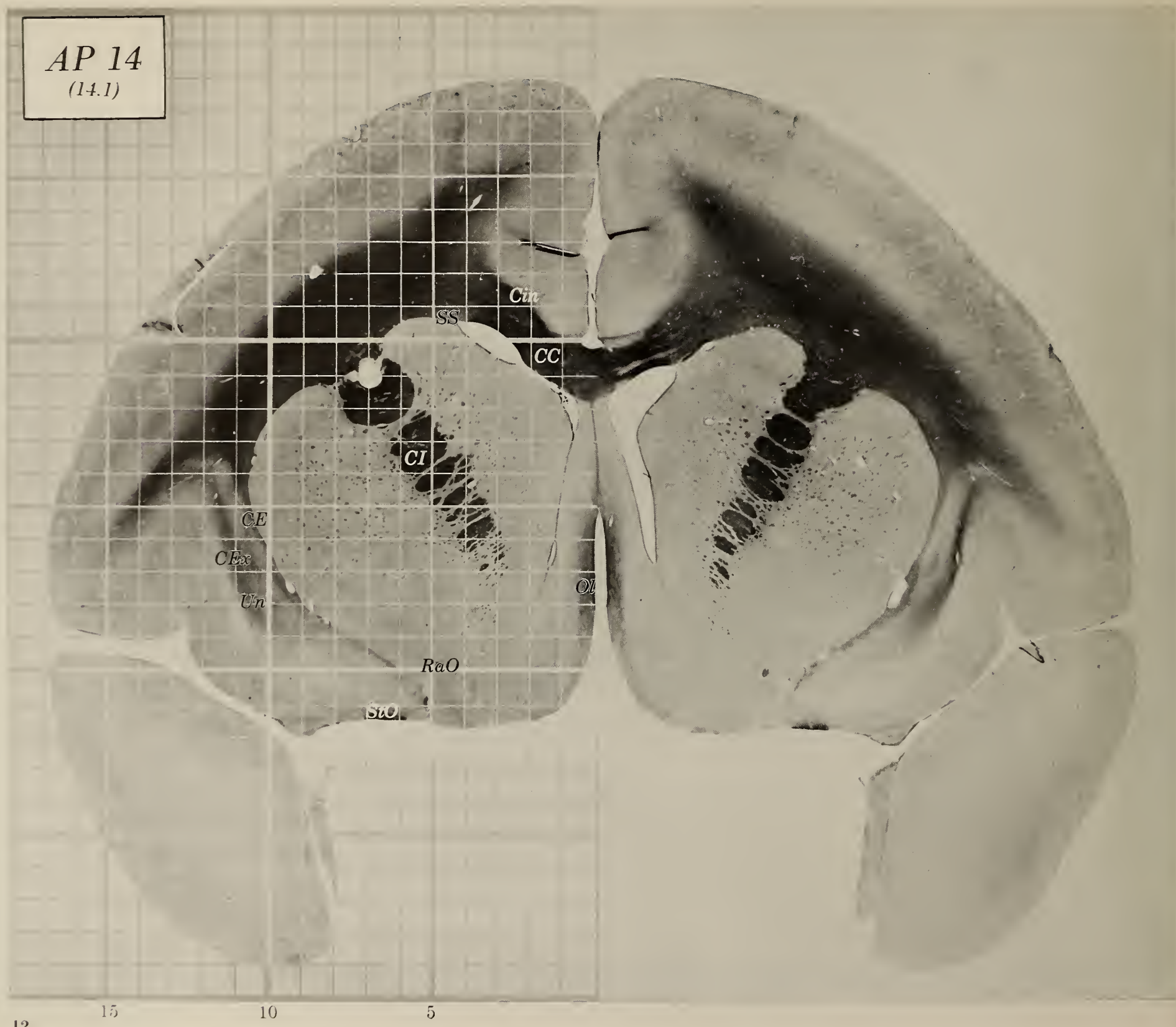
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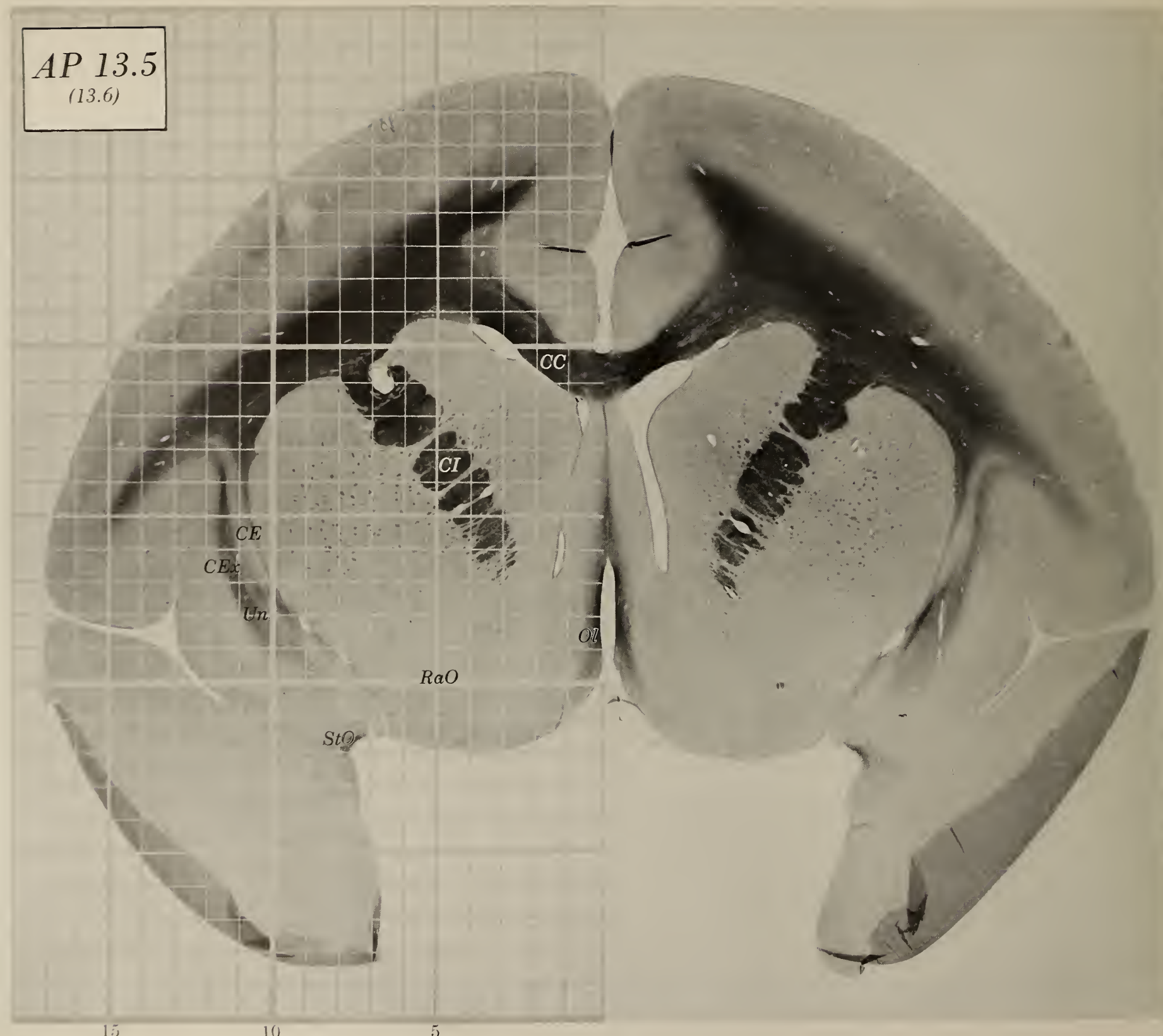
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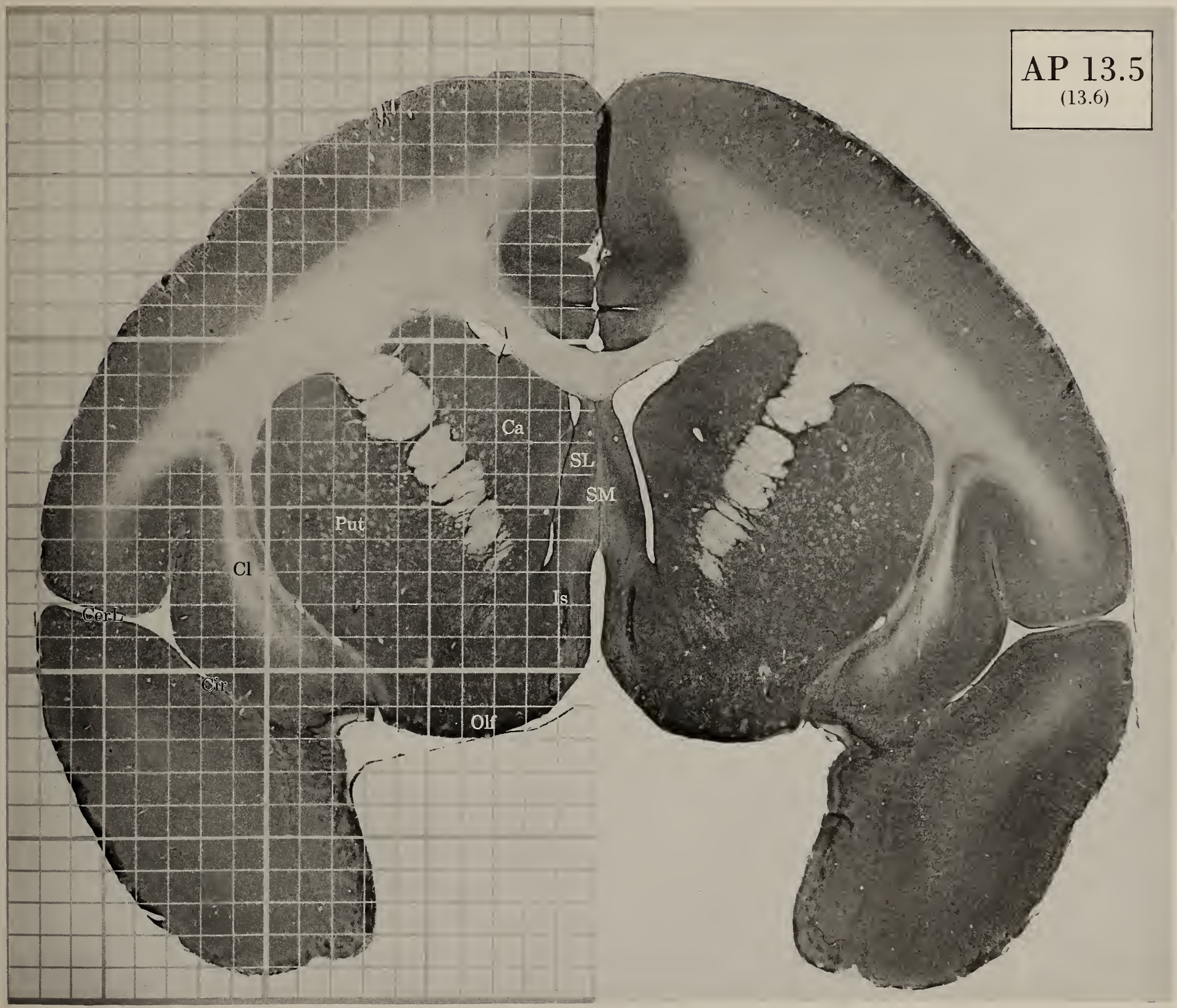
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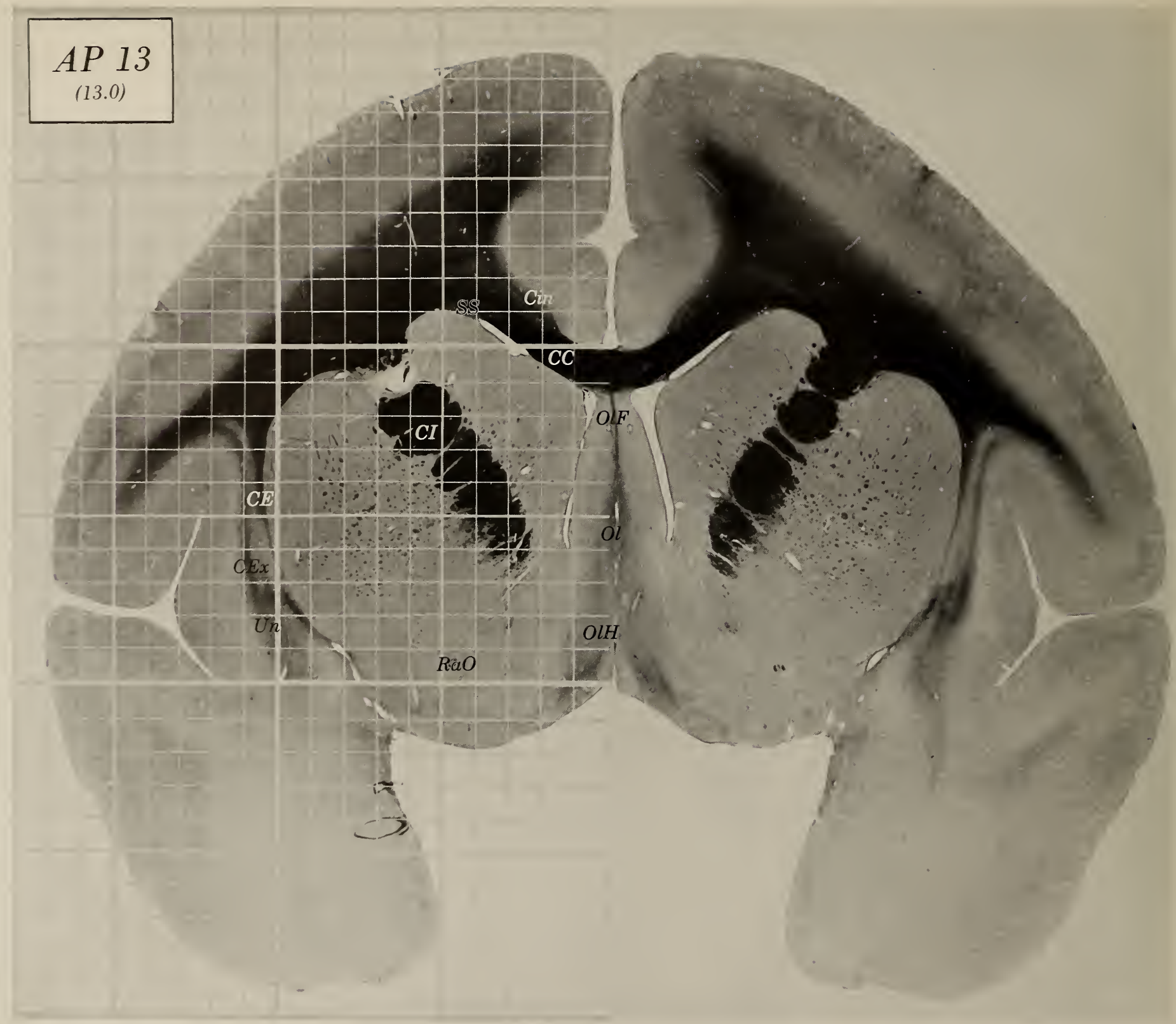
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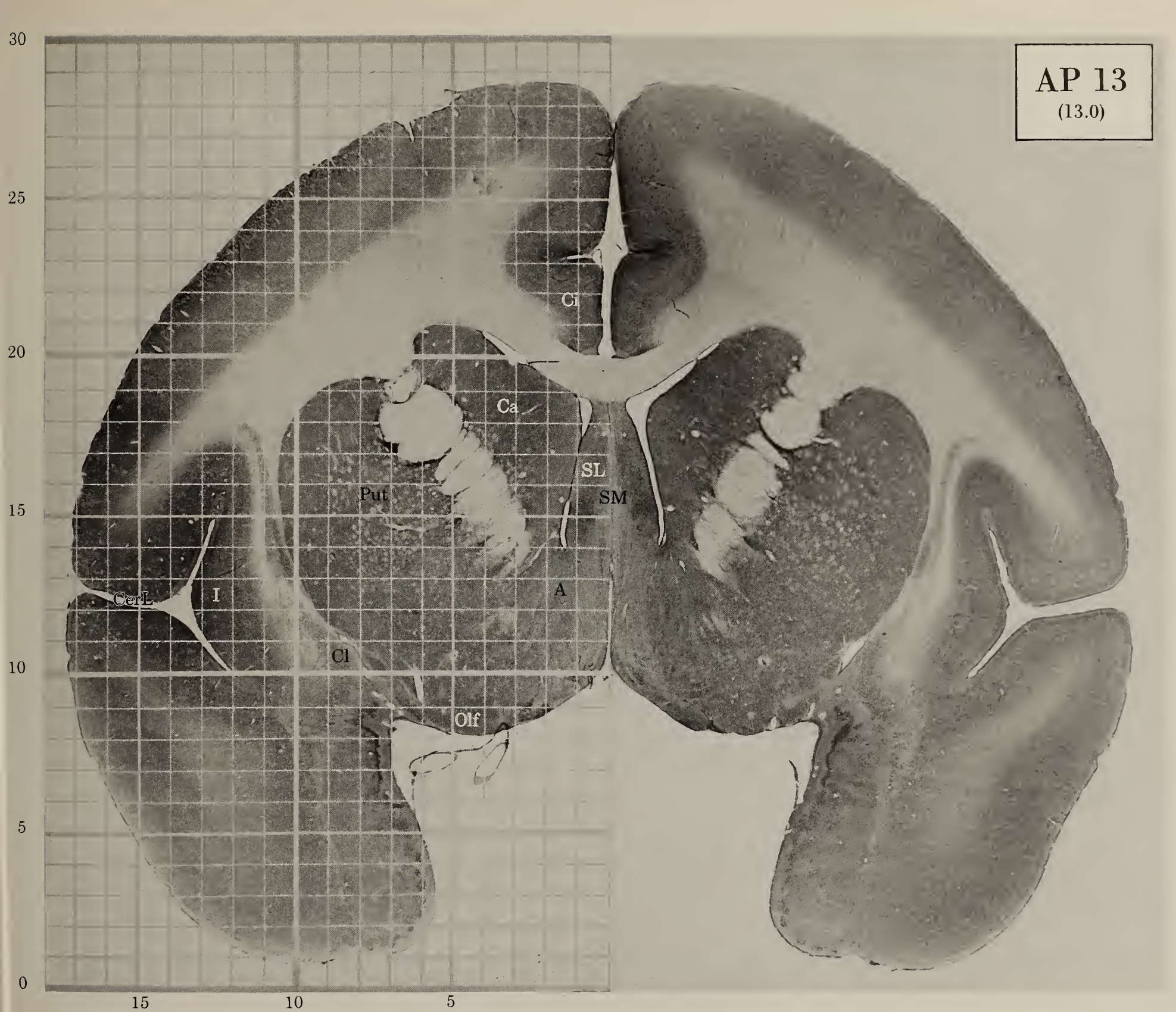
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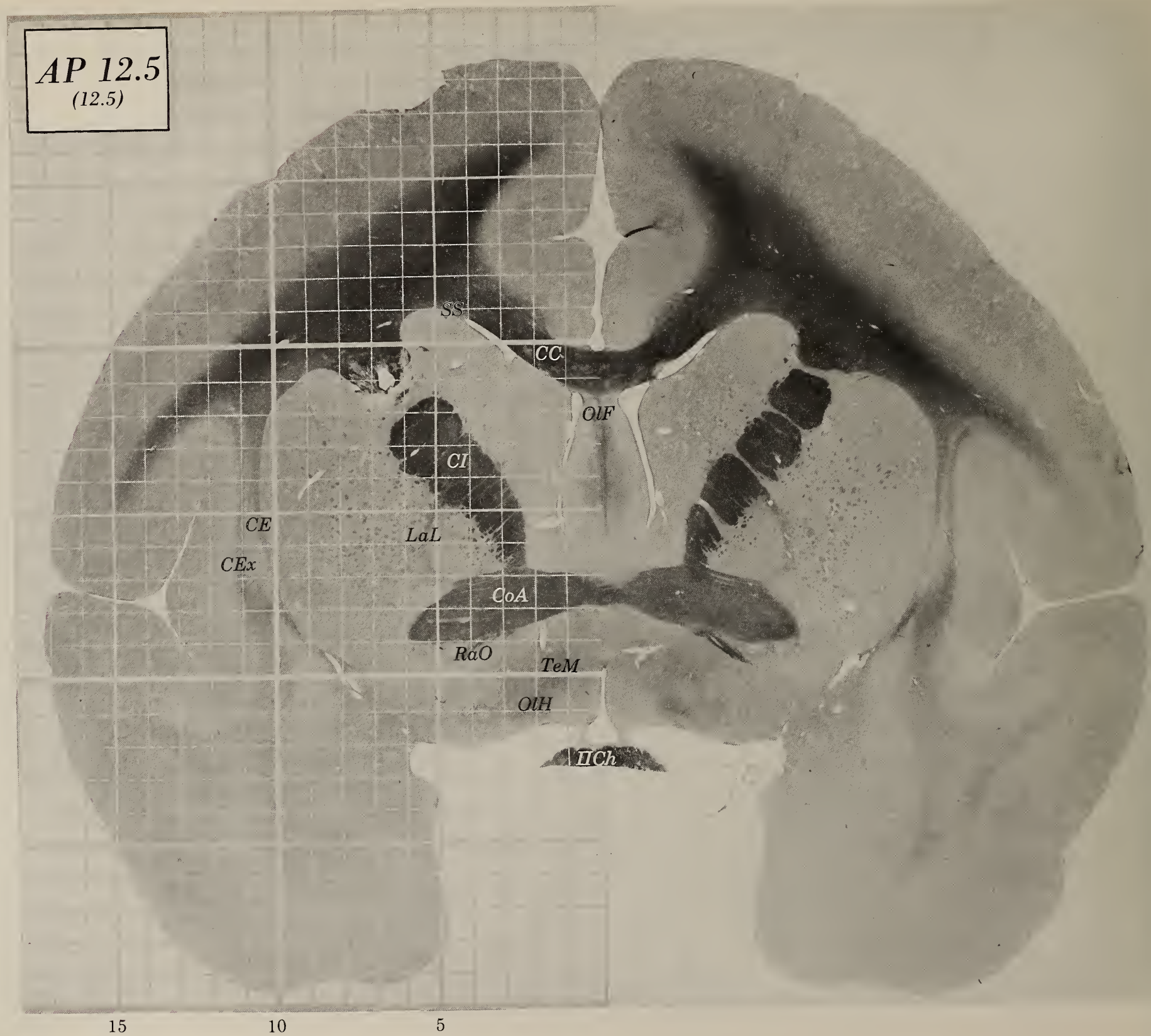
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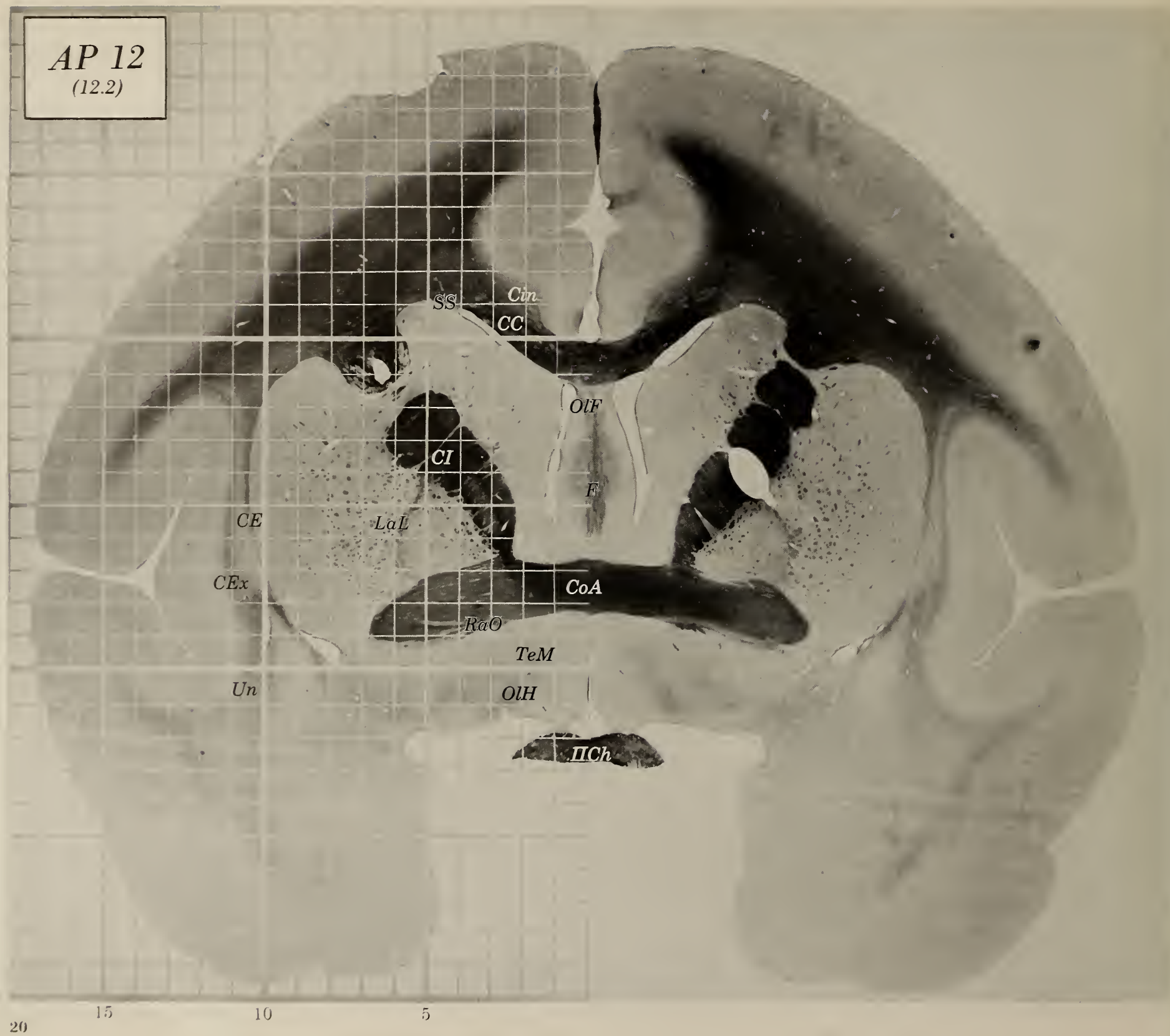
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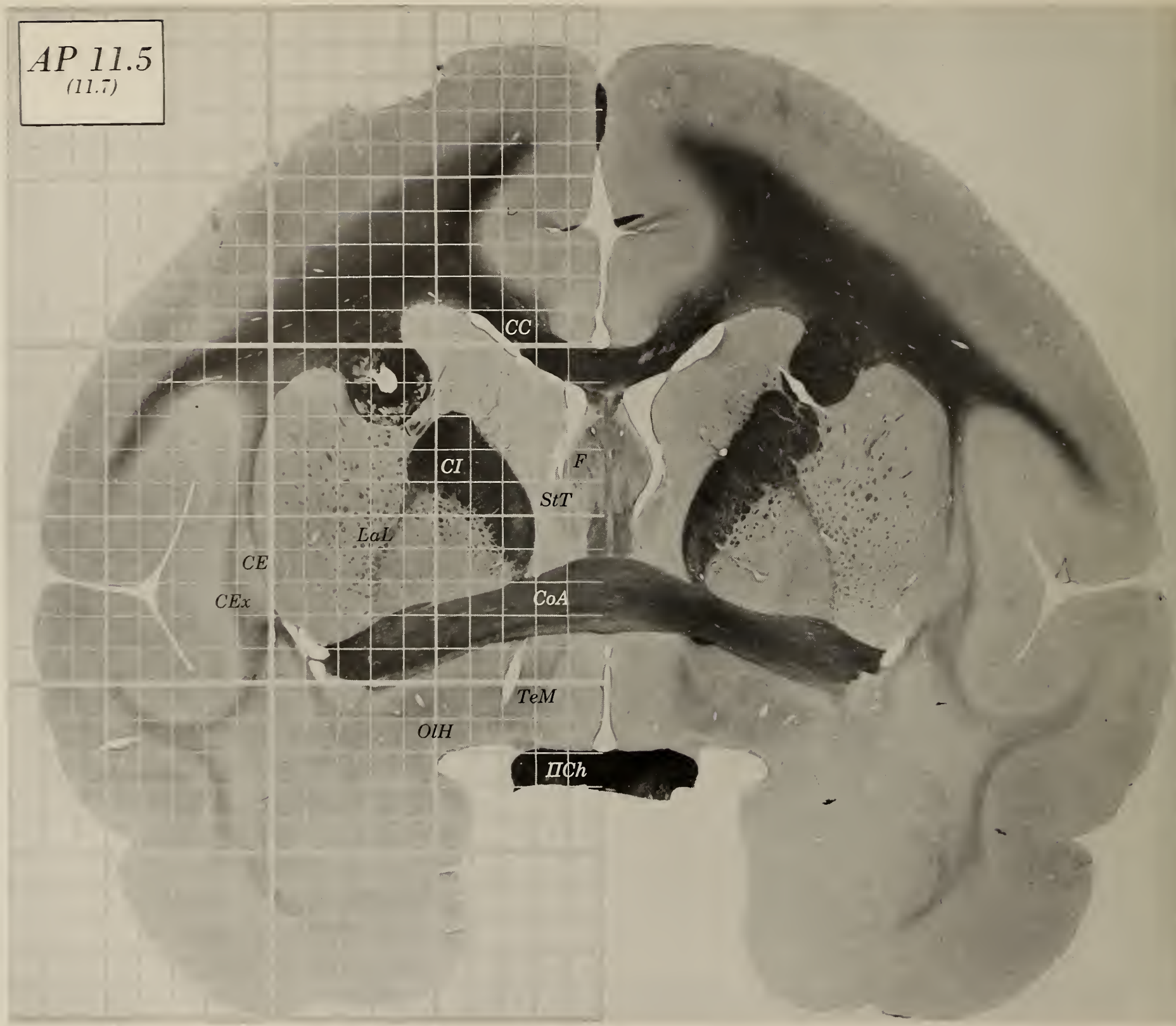
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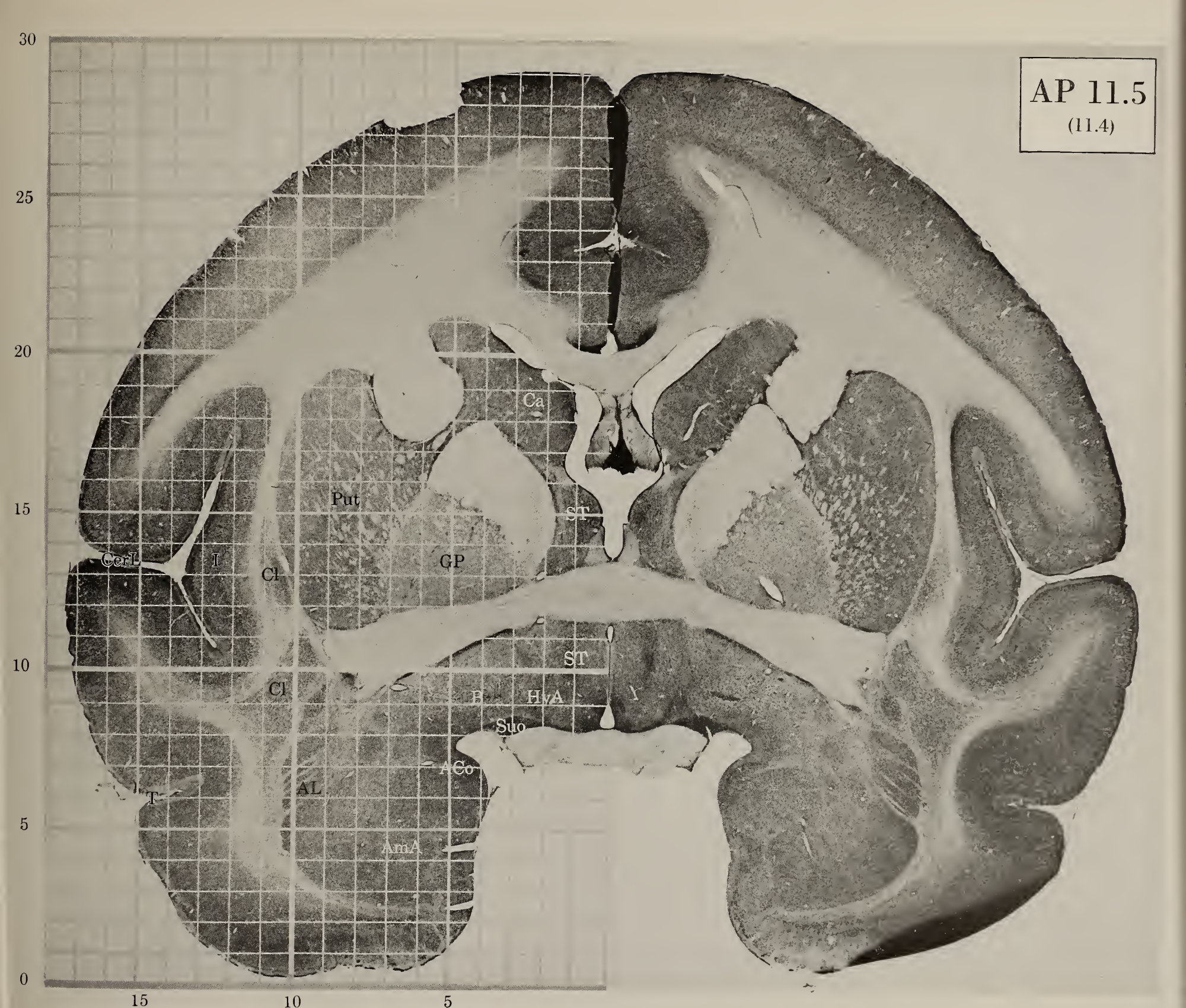
AP 11.5
(11.4)
Ca
Put
ST
CerL
I
Cl
GP
ST
Cl
HyA
Suo
ACo
AL
T
AmA
30
25
20
15
10
5
0
15
10
5

AP 11
(11.1)
SS
Cin
CC
F
StT
CI
StM
LaL
F
CEx
CE
CoA
Un
CoA
TeM
OlH
ПCh
Un
CE
30
25
20
15
10
5
0
15
10
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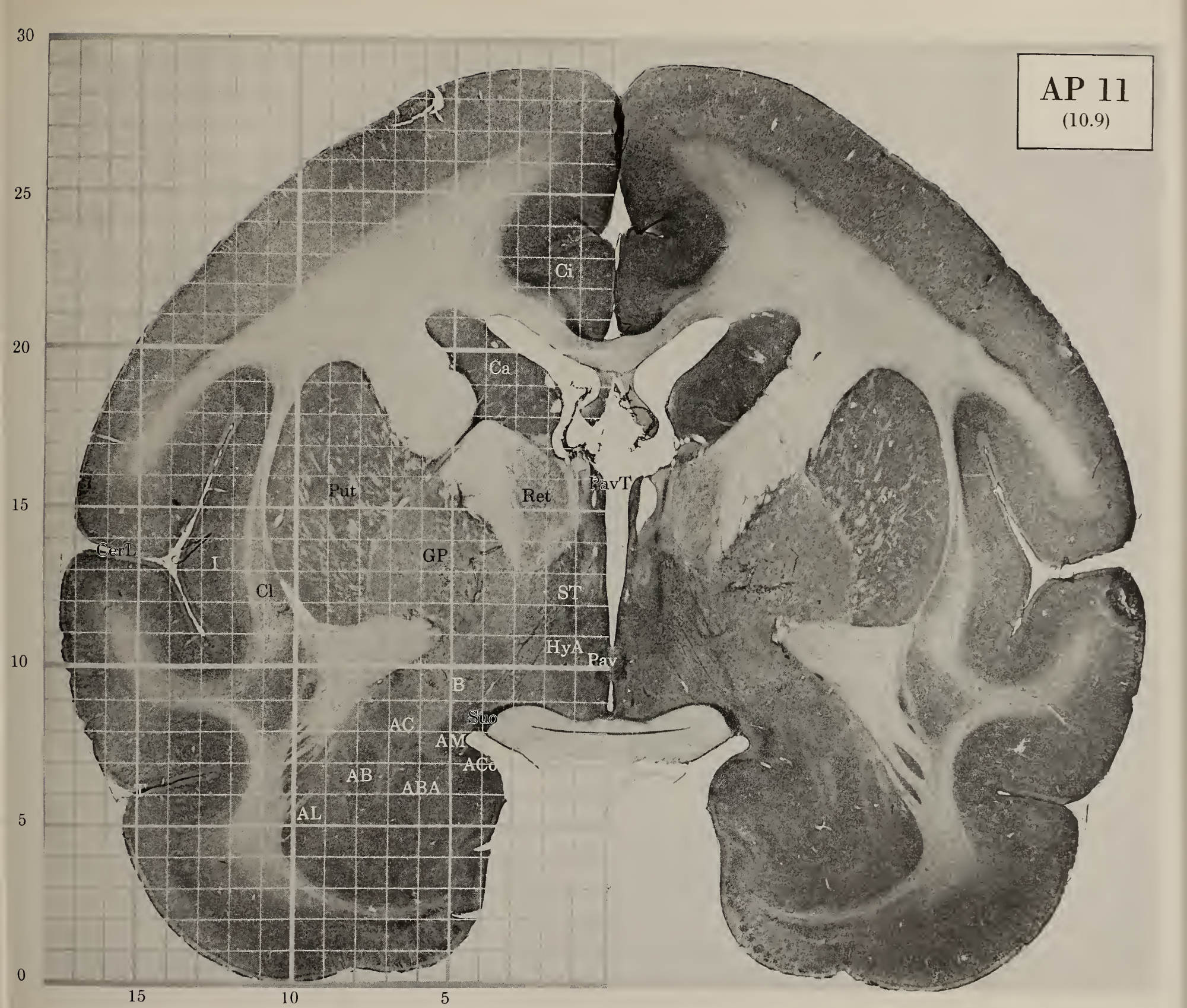
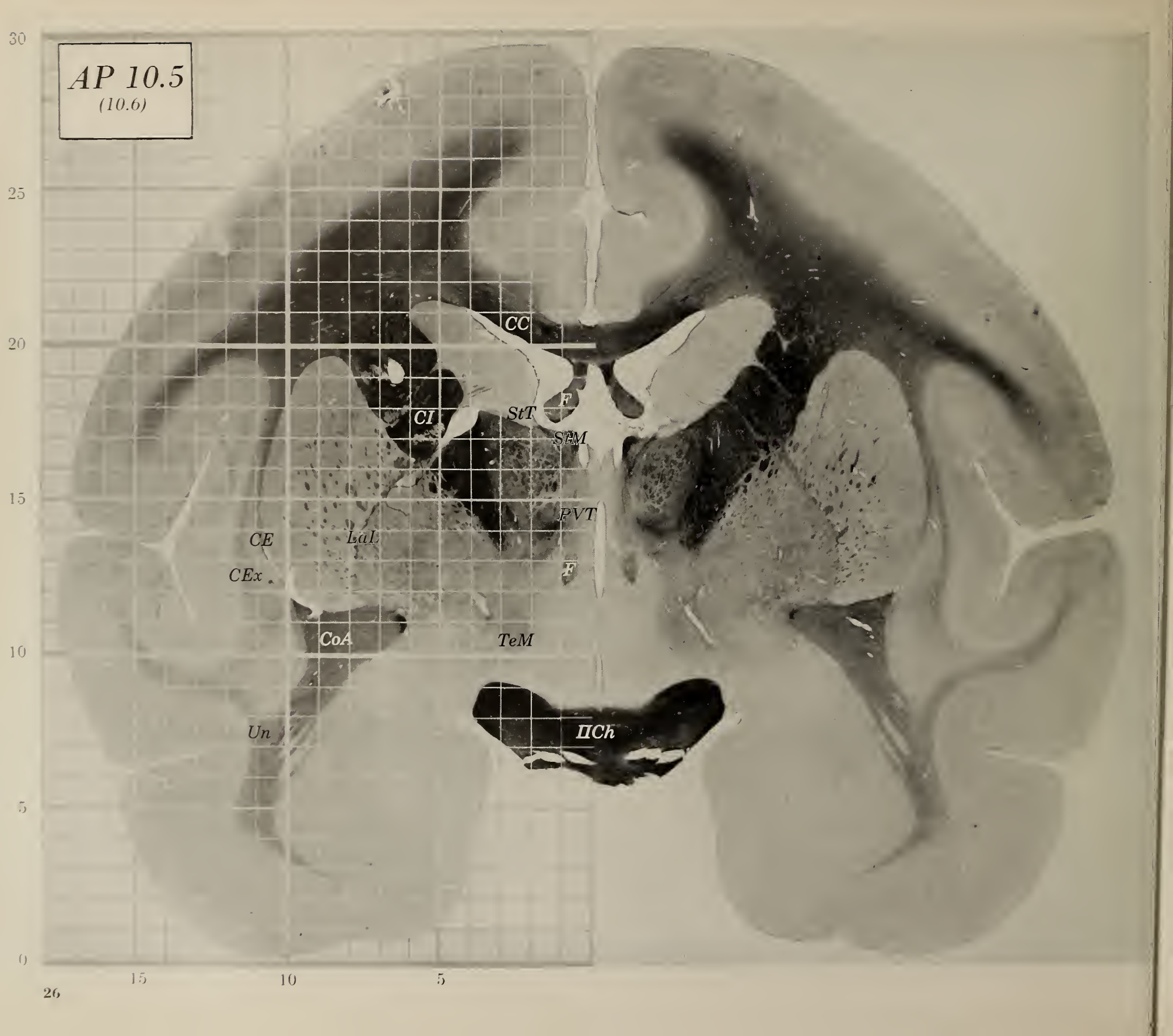
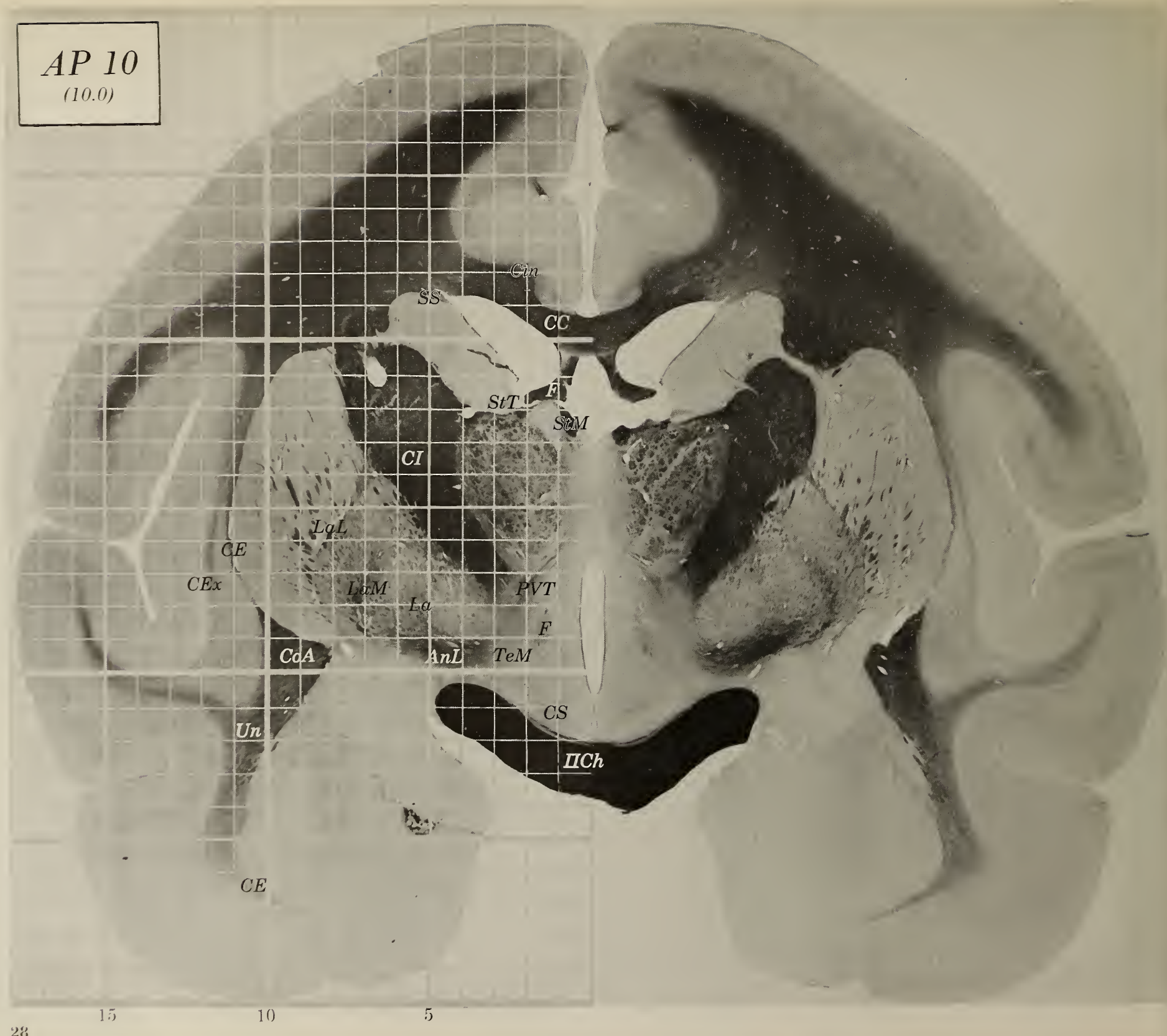

AP 11
(10.9)
30
25
20
15
10
5
0
15
10
5
Ci
Ca
Put
Ret
PavT
CerL
GP
Cl
ST
HyA
Pav
B
Suo
AC
AM
ACo
AB
ABA
AL


AP 10.5
(10.6)
CC
CI
StT
F
STM
PVT
CE
LaL
CEx
F
CoA
TeM
Un
IICh
30
25
20
15
10
5
0
15
10
5

AP 10.5
(10.6)
Ca
Ret
VA
PavT
Put
GP
CerL
Pav
HyA
Cl
AC
AM
Suo
AB
ACo
ABA
T
AL
30
25
20
15
10
5
0
15
10
5


AP 10
(10.0)
Cin
SS
CC
StT
F
StM
CI
LaL
CE
CEx
LaM
La
PVT
F
CoA
AnL
TeM
CS
Un
IICh
CE
30
25
20
15
10
5
0
15
10
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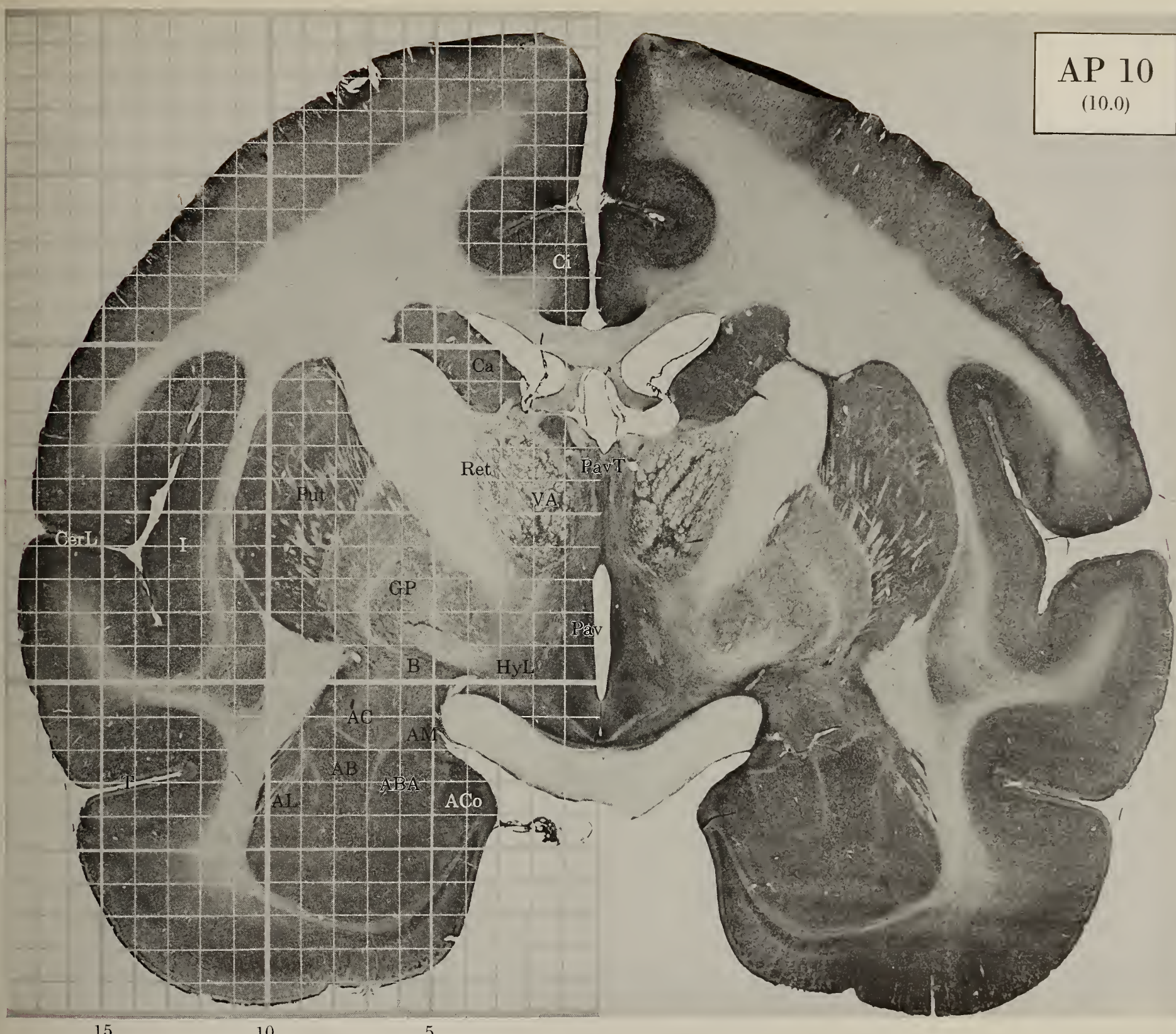
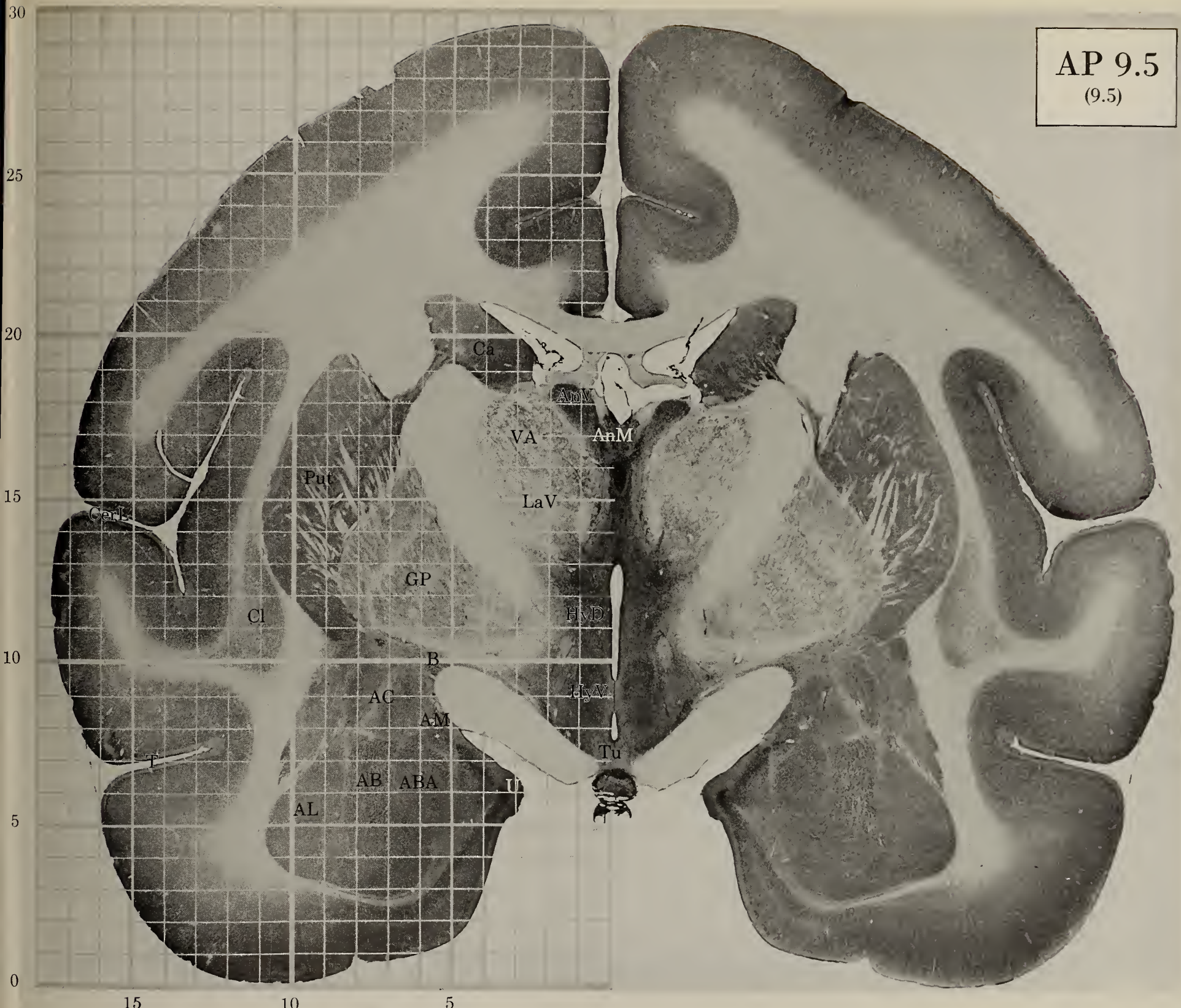

AP 10
(10.0)
Ci
Ca
Ret
PavT
Put
VA
CerL
I
GP
Pav
B
HyL
AC
AM
AB
ABA
T
AL
ACo
30
25
20
15
10
5
0
15
10
5

AP 9.5
(9.5)
CC
F
StT
StM
CI
PVT
MT
CE
LaL
LaM
CEx
AnL
F
CSD
IIT
30
25
20
15
10
5
0
15
10
5
30


AP 9.5
(9.5)
Ca
AnV
VA
AnM
Put
LaV
CerL
GP
Cl
HyD
B
AC
HyV
AM
Tu
T
AB
ABA
AL
30
25
20
15
10
5
0
15
10
5

AP 9
(9.0)
Cn
SS
CC
F
StT
StM
LaT
CI
LaL
CE
CEx
LaM
MT
AnL
F
IIT
TeM
StT
CE
30
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20
15
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0
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10
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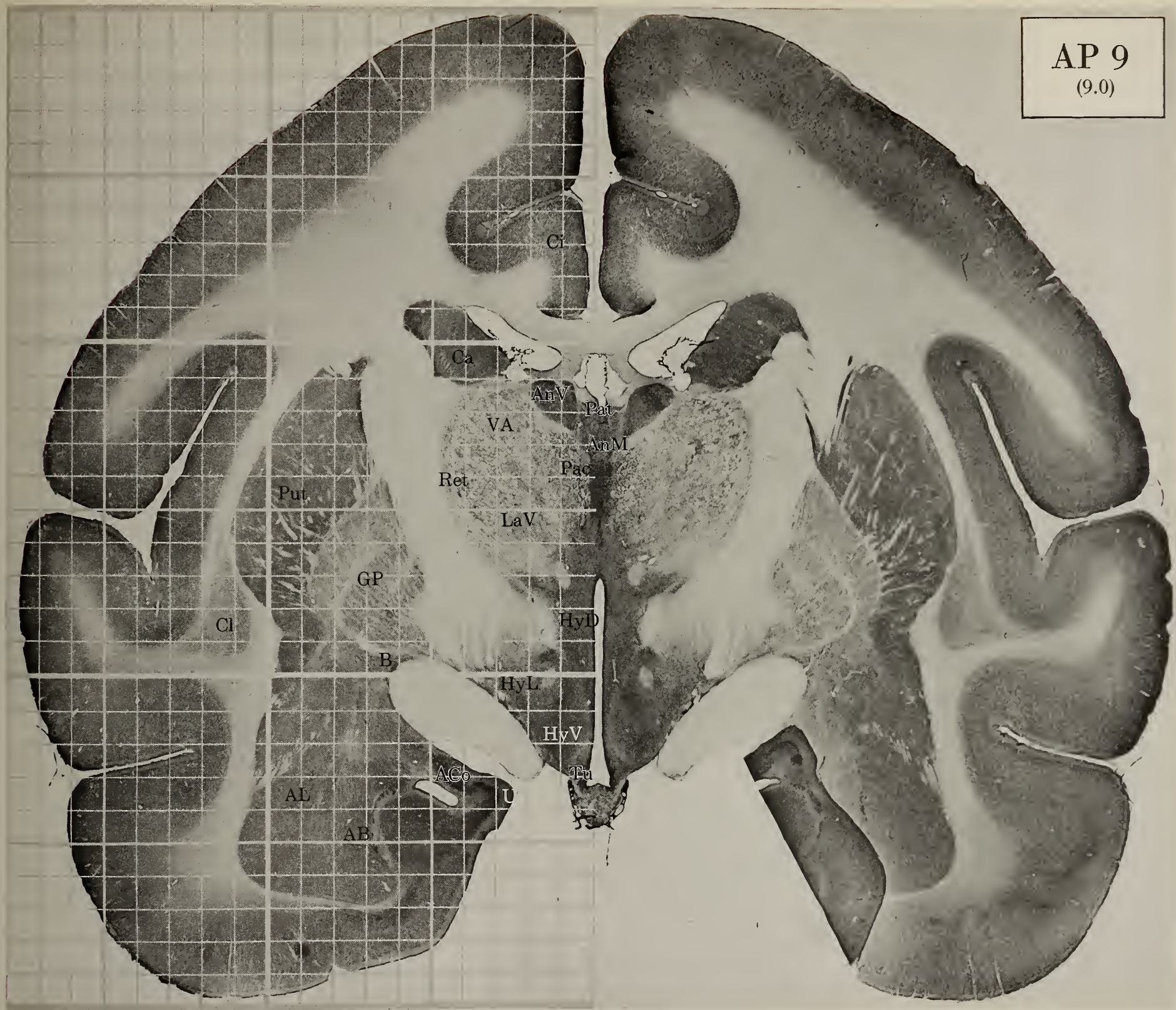
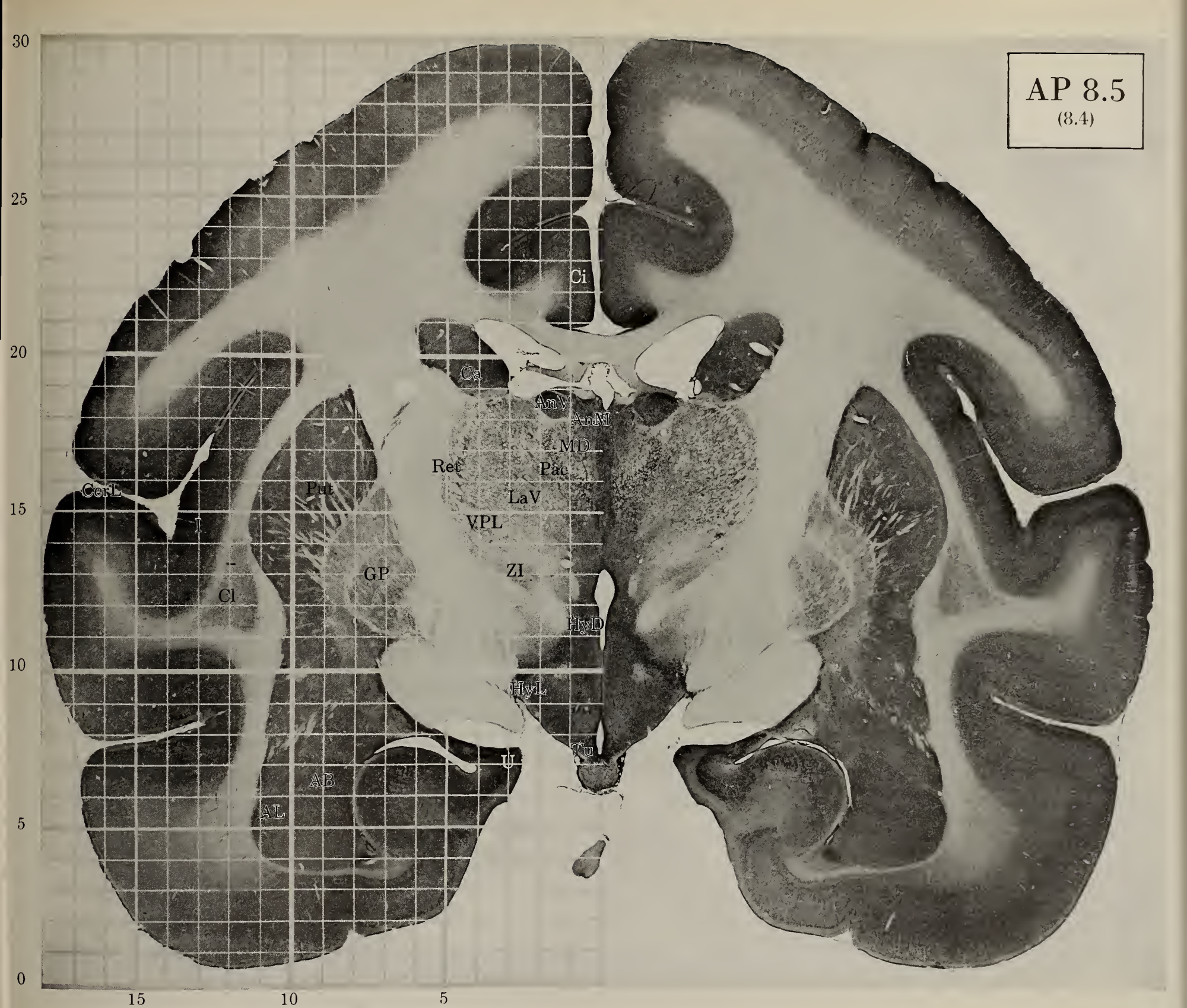
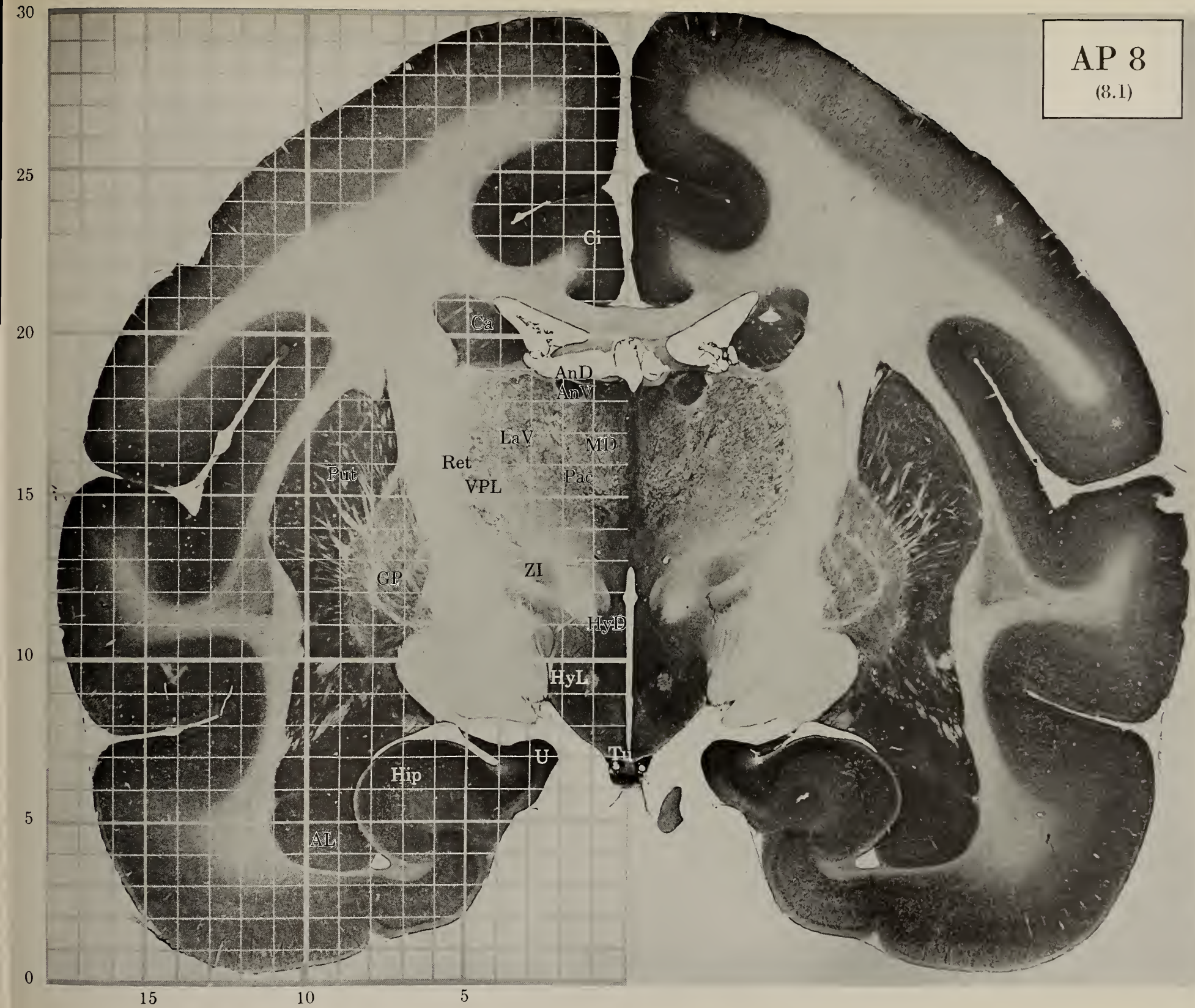

AP 9
(9.0)
Ci
Ca
AnV
Pat
VA
AnM
Pac
Ret
Put
LaV
GP
Cl
HyD
B
HyL
HyV
ACo
Tu
AL
AB
30
25
20
15
10
5
0
15
10
5

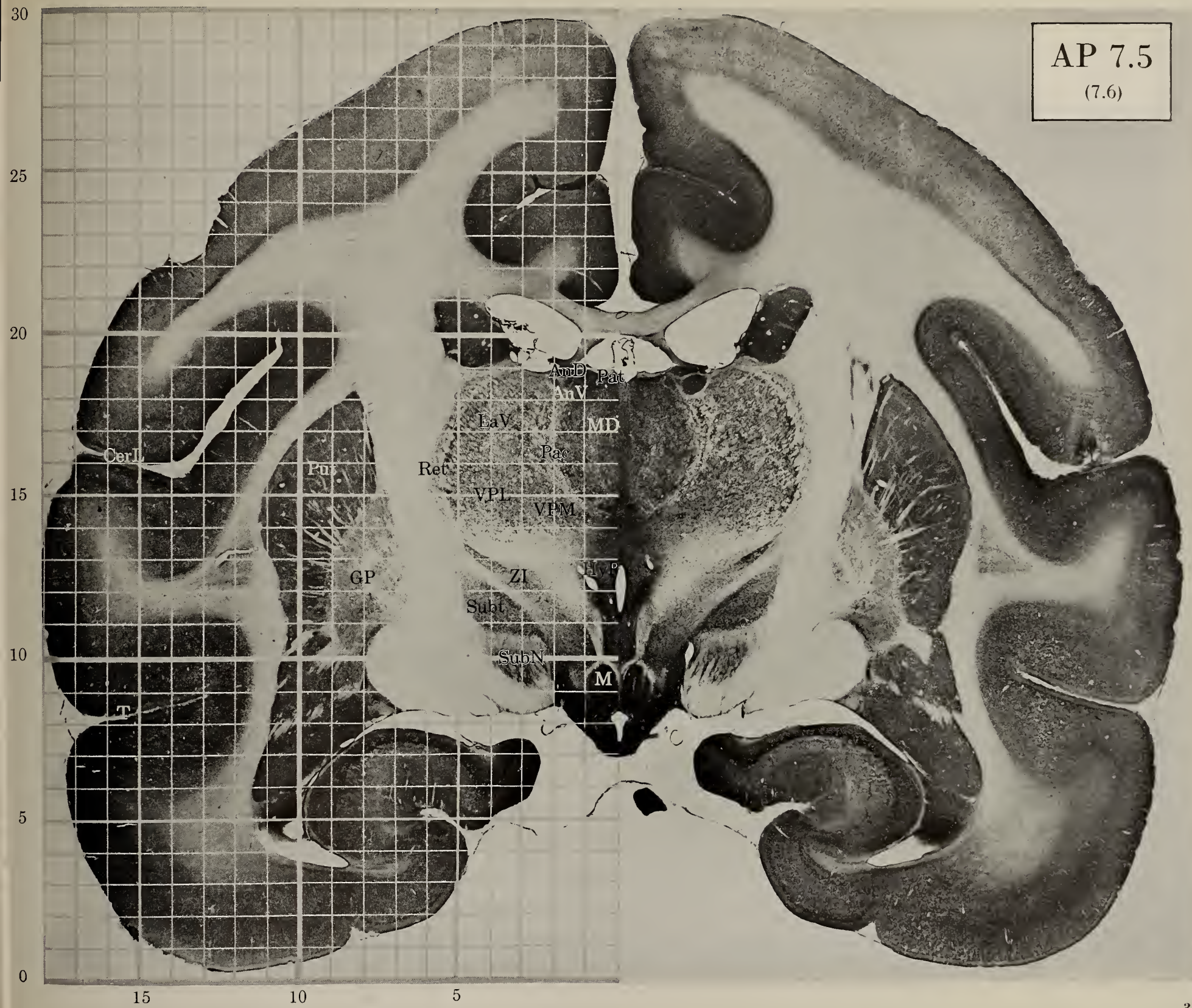
AP 8.5
(8.4)
CC
F
StT
StM
LaLT
LaMT
CI
LaL
LaM
CE
CEx
H1
H2
MT
AnL
HT
F
StT
30
25
20
15
10
5
0
15
10
5

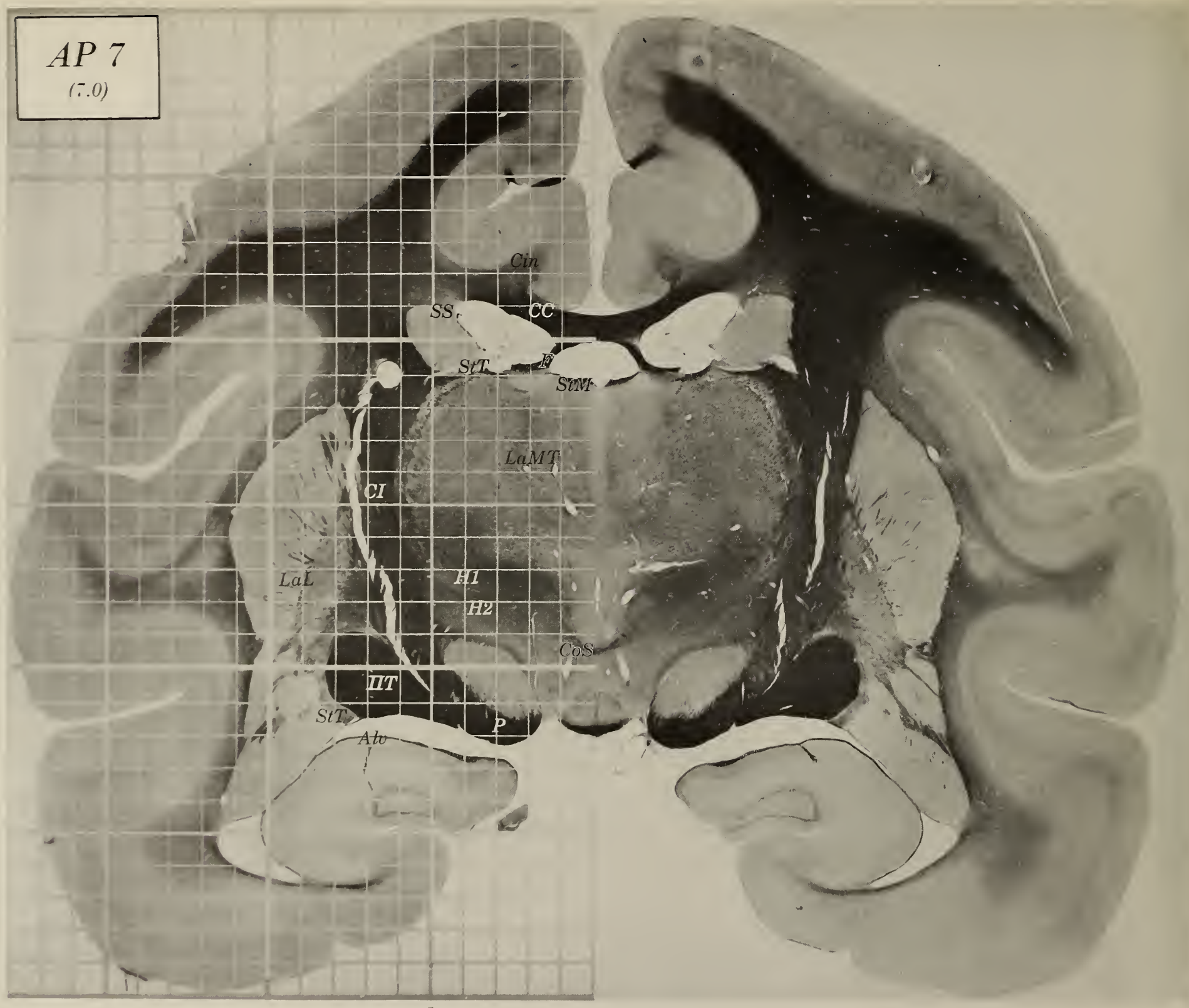

AP 8.5
(8.4)
Ci
Ca
AnV
AnM
MD
Ret
Pac
LaV
VPL
ZI
CerL
Put
I
Cl
GP
HyD
HyL
Tu
U
AB
AL
30
25
20
15
10
5
0
15
10
5

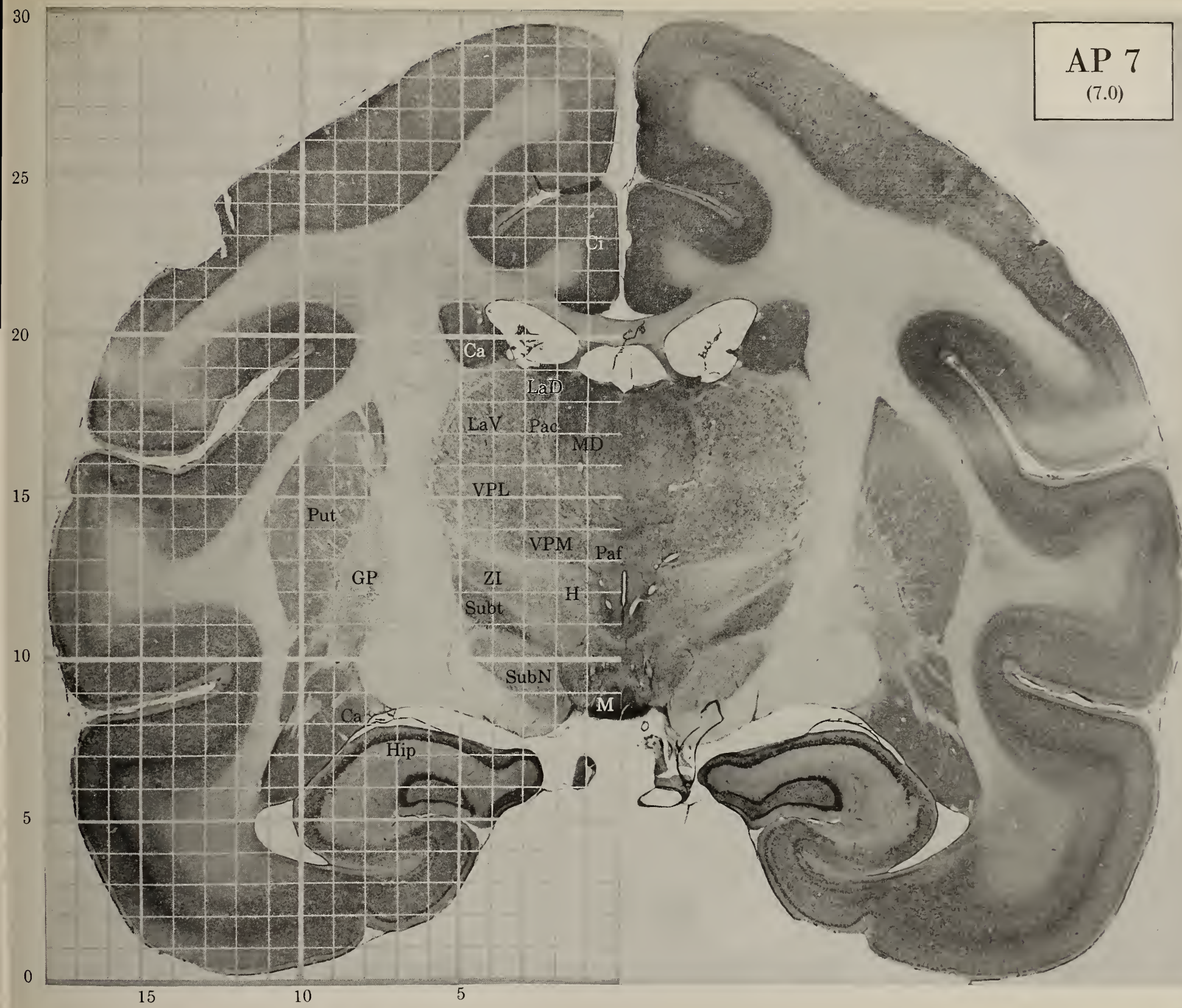
AP 8
(7.9)
Cin
SS
CC
StT
F
StM
LaLT
LaMT
CI
CE
LaL
CEx
LaM
H1
H2
AnL
MT
IIT
P
StT
Alv
30
25
20
15
10
5
0
15
10
5
36


AP 8
(8.1)
Ci
Ca
AnD
AnV
LaV
MD
Ret
Put
VPL
Pac
ZI
GP
HyD
HyL
U
Tu
Hip
AL
30
25
20
15
10
5
0
15
10
5

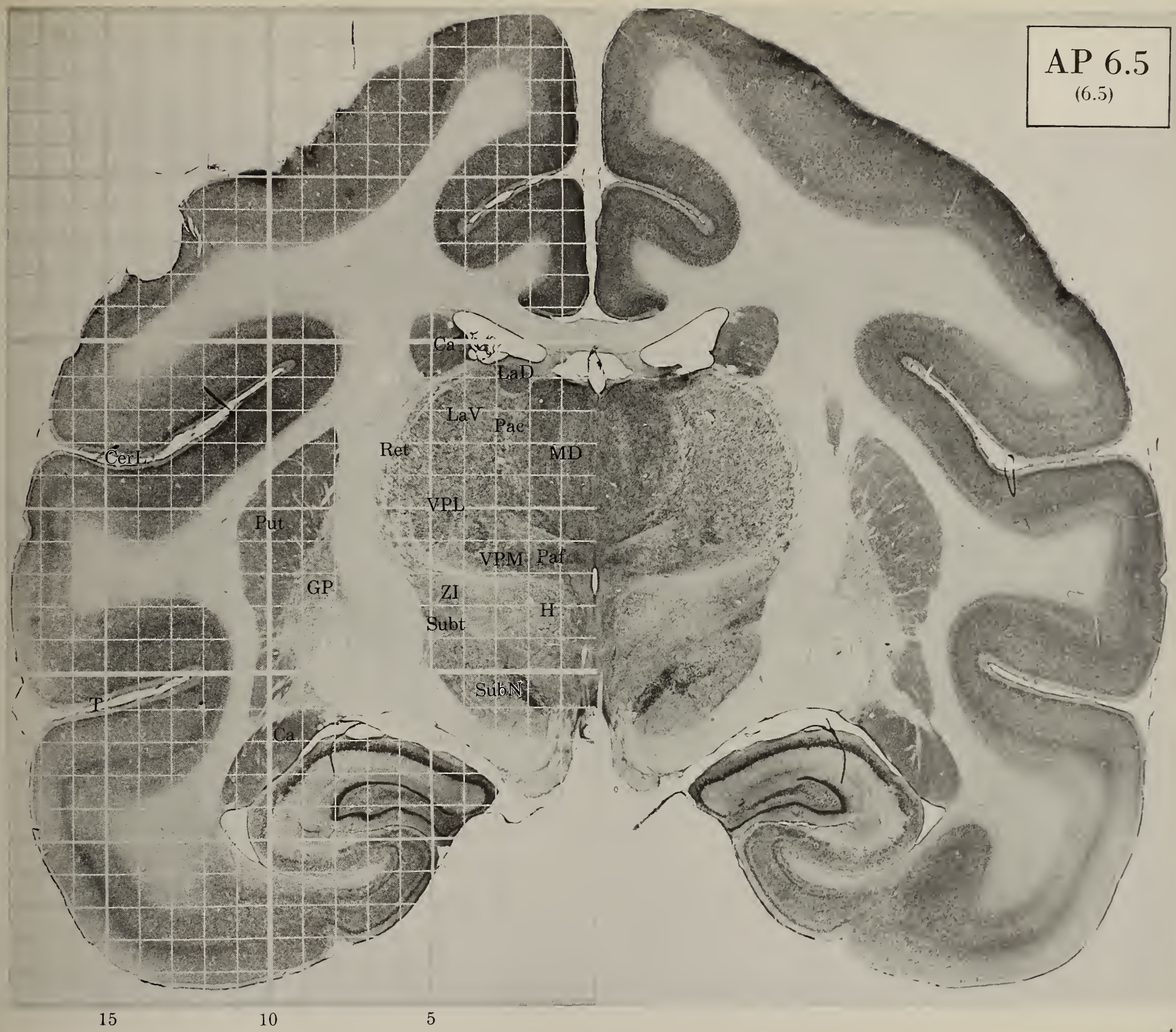
AP 7.5
(7.6)
CC
StT
StM
LaMT
CI
LaLT
Laul
H1
H2
MT
IIT
StT
P
Alv
30
25
20
15
10
5
0
15
10
5


AP 7.5
(7.6)
AmD
Pat
AmV
LaV
MD
CerL
Pac
Ret
Pu
VPL
VPM
GP
ZI
Hyp
Subt
SubN
M
T
30
25
20
15
10
5
0
15
10
5


AP 7
(7.0)
Cin
SS
CC
StT
F
StM
LaMT
CI
LaL
H1
H2
CoS
IIT
StT
P
Alv
30
25
20
15
10
5
0
15
10
5
10


AP 7
(7.0)
Ci
Ca
LaD
LaV
Pac
MD
VPL
Put
VPM
Paf
GP
ZI
H
Subt
SubN
M
Ca
Hip
30
25
20
15
10
5
0
15
10
5

AP 6.5
(6.5)
CC
StT
E
StM
LaMT
LaLT
CI
H1
H2
CoS
IIT
StT
Alv
P
III
Cin
30
25
20
15
10
5
0
15
10
5


AP 6.5
(6.5)
Ca
LaD
LaV
Pac
Ret
MD
CerL
VPL
Put
VPM
Paf
GP
ZI
H
Subt
SubN
T
Ca
30
25
20
15
10
5
0
15
10
5

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AP 6
(6.0)
Cin
StT
T
StM
LaMT
CI
LM
HI
Alv
P
SSP
30
25
20
15
10
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0
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10
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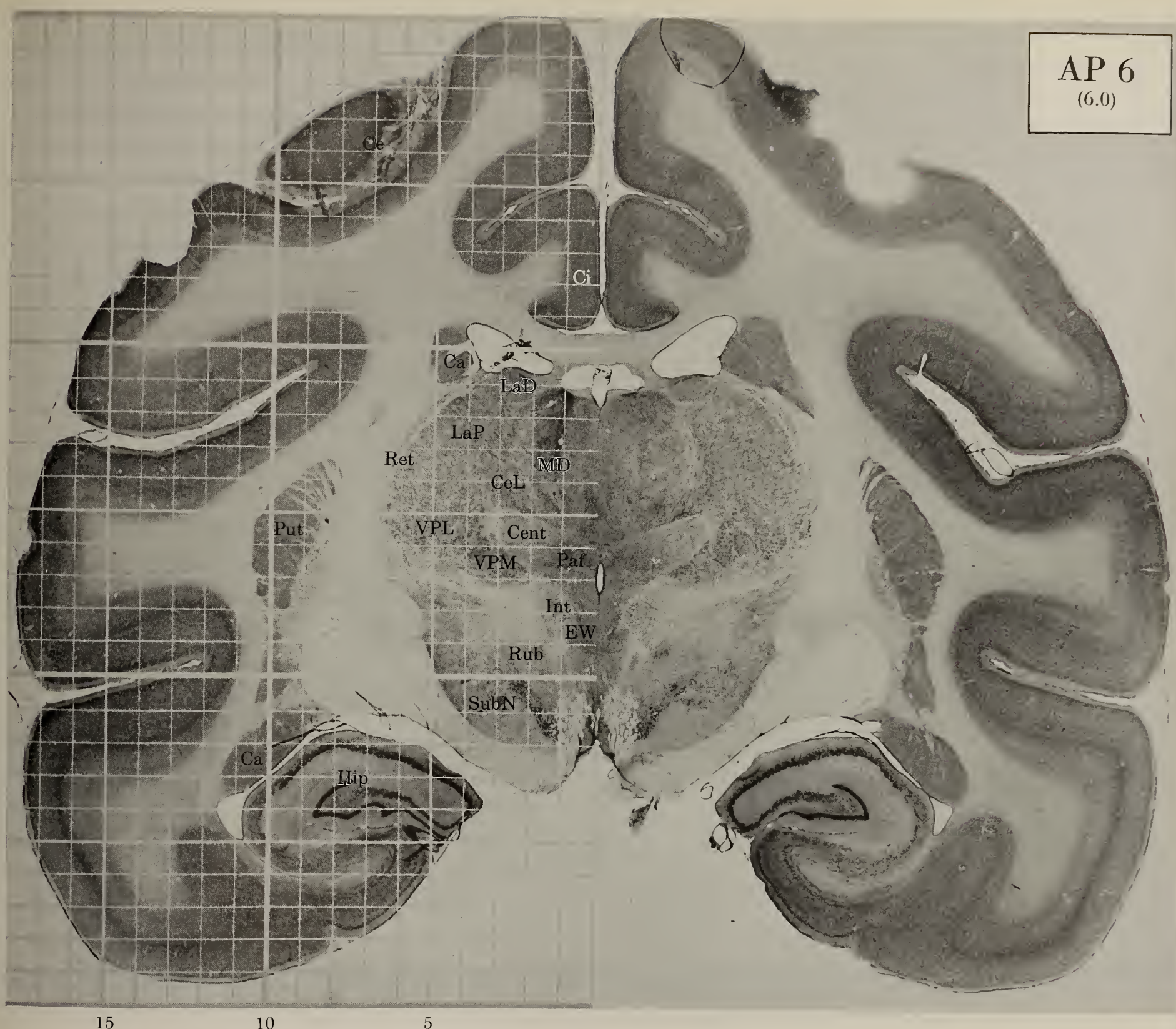
AP 6
(6.0)
Ce
Ci
Ca
LaD
LaP
Ret
MD
CeL
Put
VPL
Cent
VPM
Paf
Int
EW
Rub
SubN
Ca
Hip
30
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20
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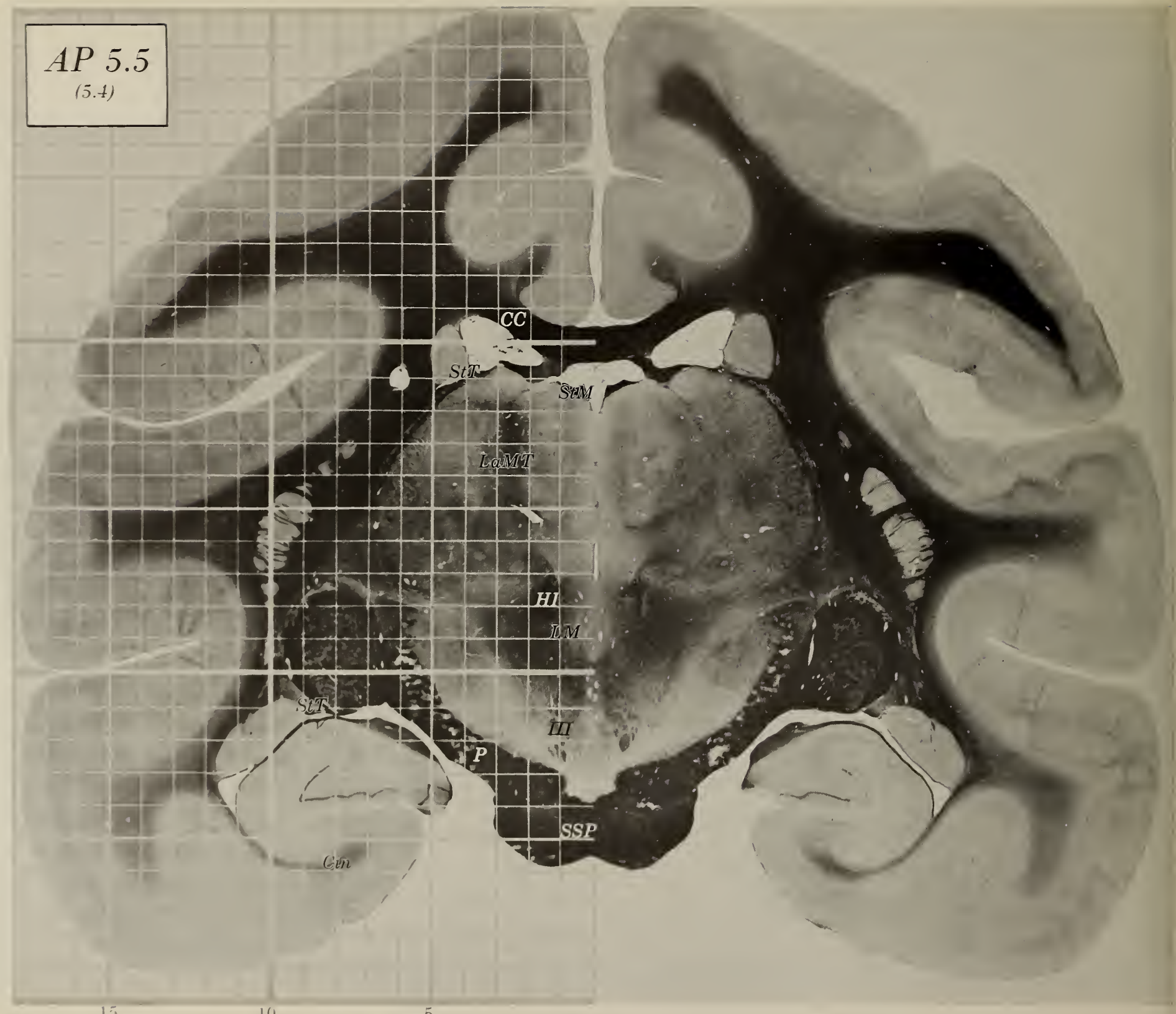
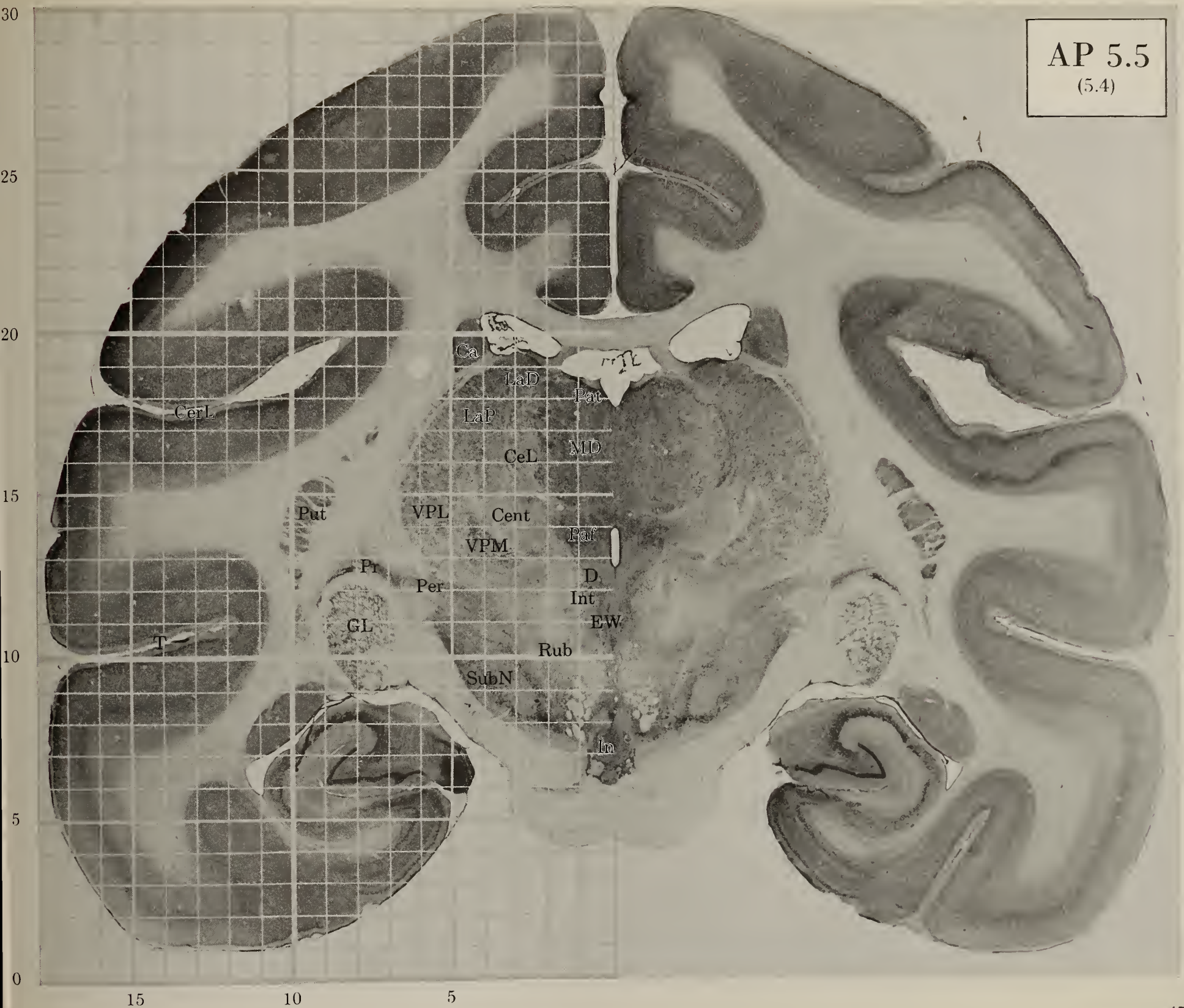

AP 5.5
(5.4)
CC
StT
StM
LaMT
HI
LM
StT
III
P
SSP
Cin
30
25
20
15
10
5
0
15
10
5


AP 5.5
(5.4)
Ca
LaD
Pat
CerL
LaP
CeL
MD
Put
VPL
Cent
VPM
Paf
Pr
Per
D
Int
GL
EW
T
Rub
SubN
In
30
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20
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0
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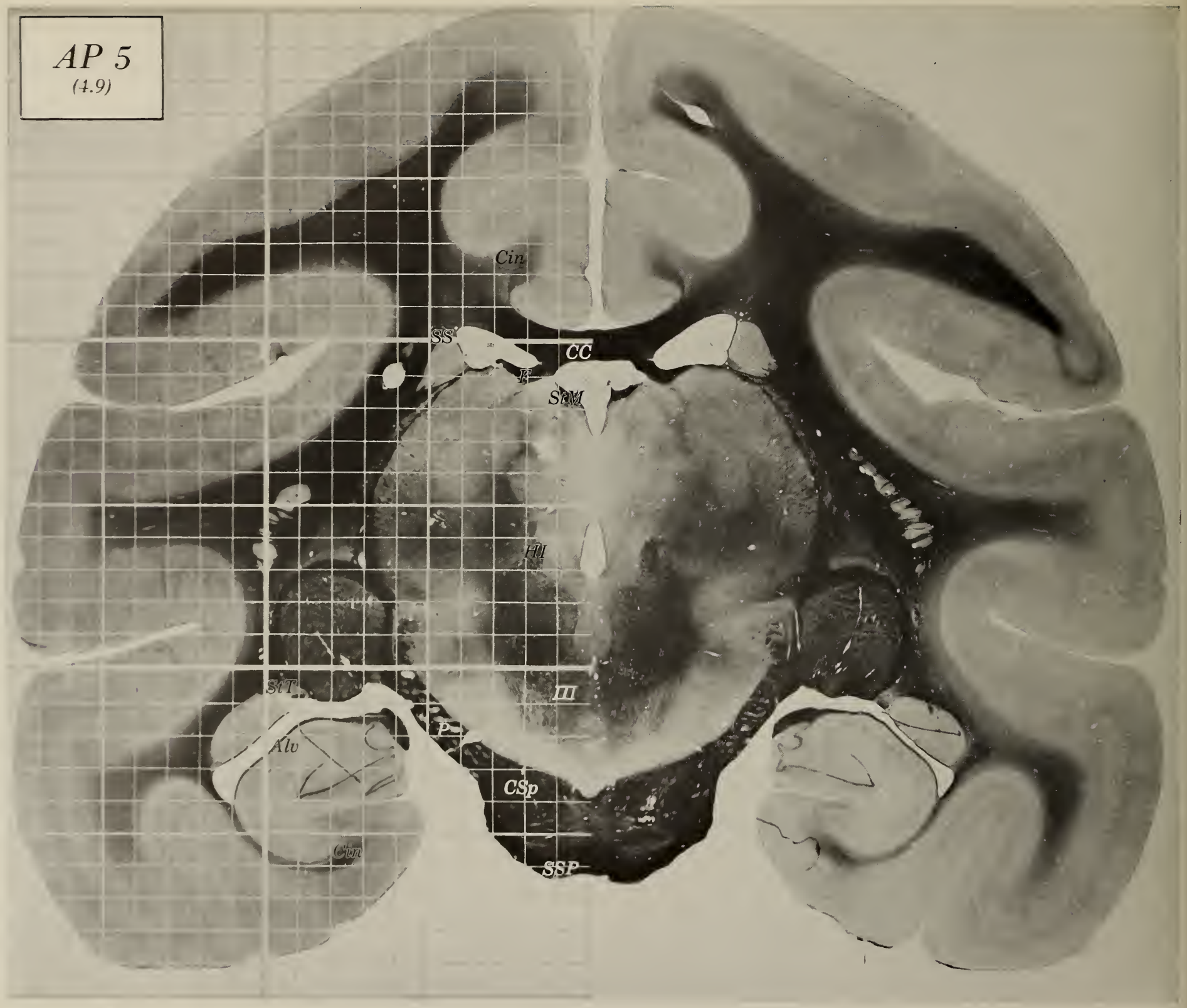
AP 5
(4.9)
Cin
SS
CC
F
SM
HI
III
StT
P
Alv
CSp
Cin
SSP
30
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20
15
10
5
0
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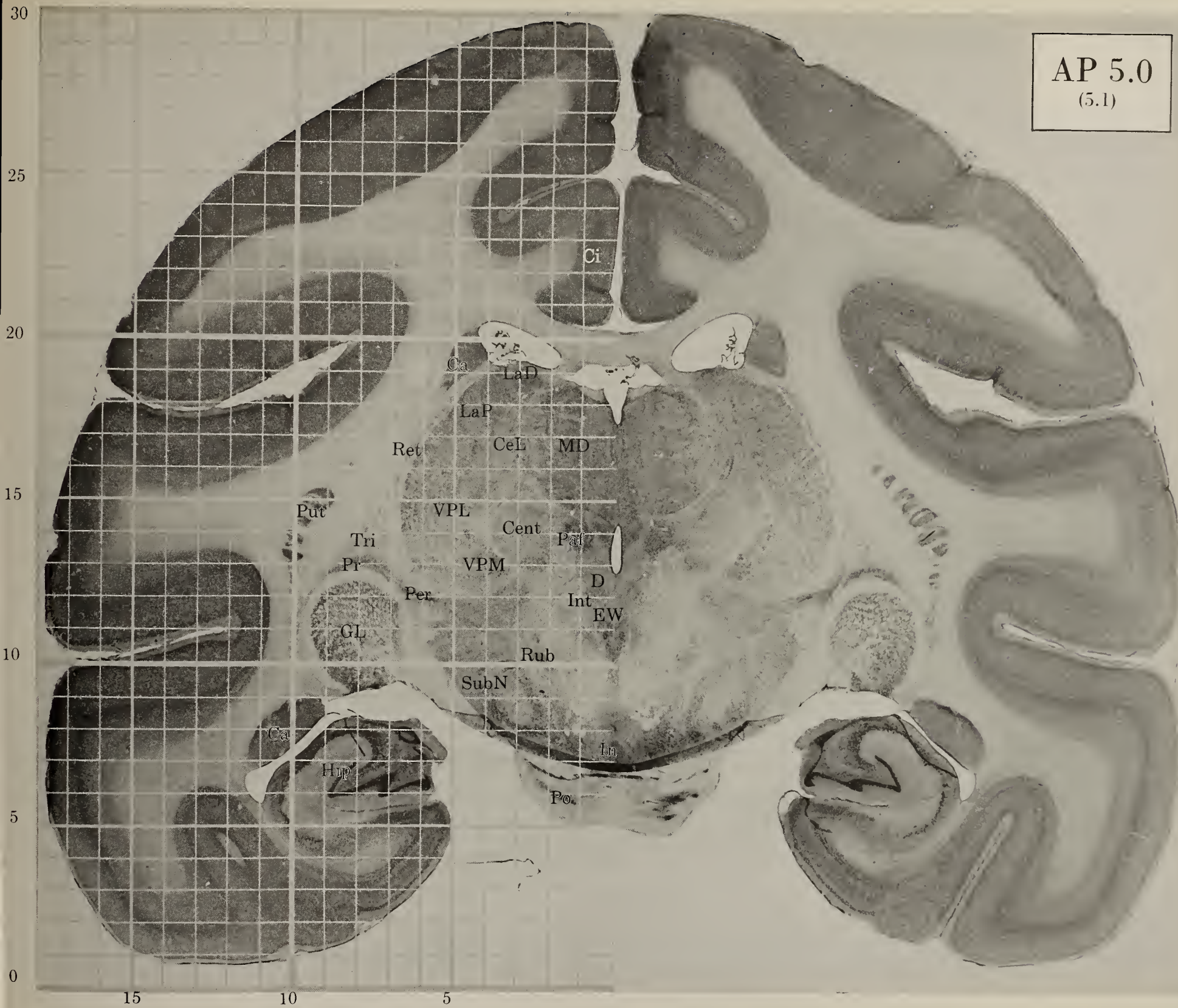
10
5


AP 5.0
(5.1)
Ci
Ca
LaD
LaP
Ret
CeL
MD
Put
VPL
Cent
Paf
Tri
Pr
VPM
D
Per
Int
EW
GL
Rub
SubN
Ca
In
Hip
Po
30
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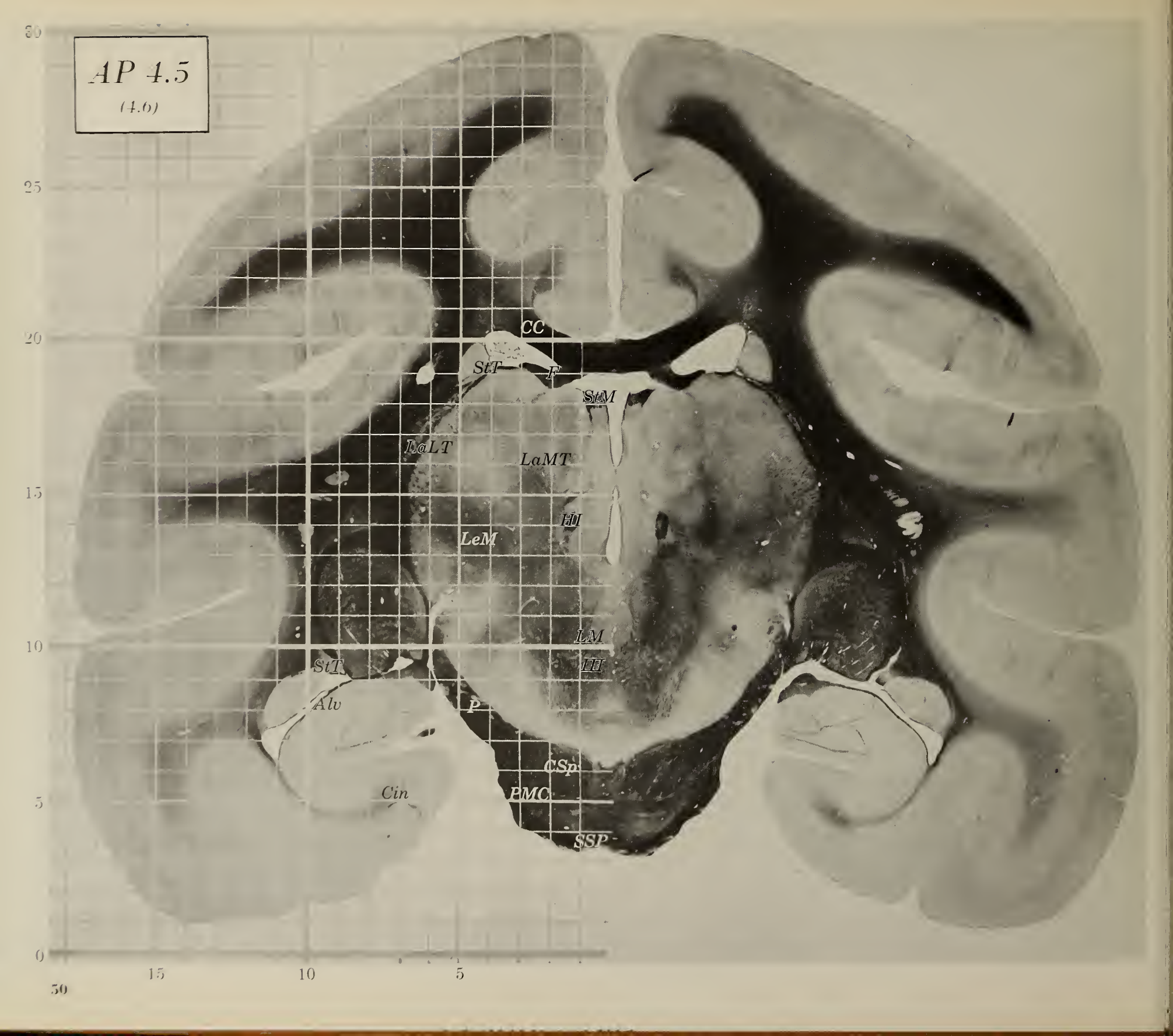
20
15
10
5
0
15
10
5


AP 4.5
(4.6)
CC
StT
F
StM
LaLT
LaMT
HI
LeM
LM
LII
StT
Alv
P
CSp
Cin
PMC
SSP
30
25
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15
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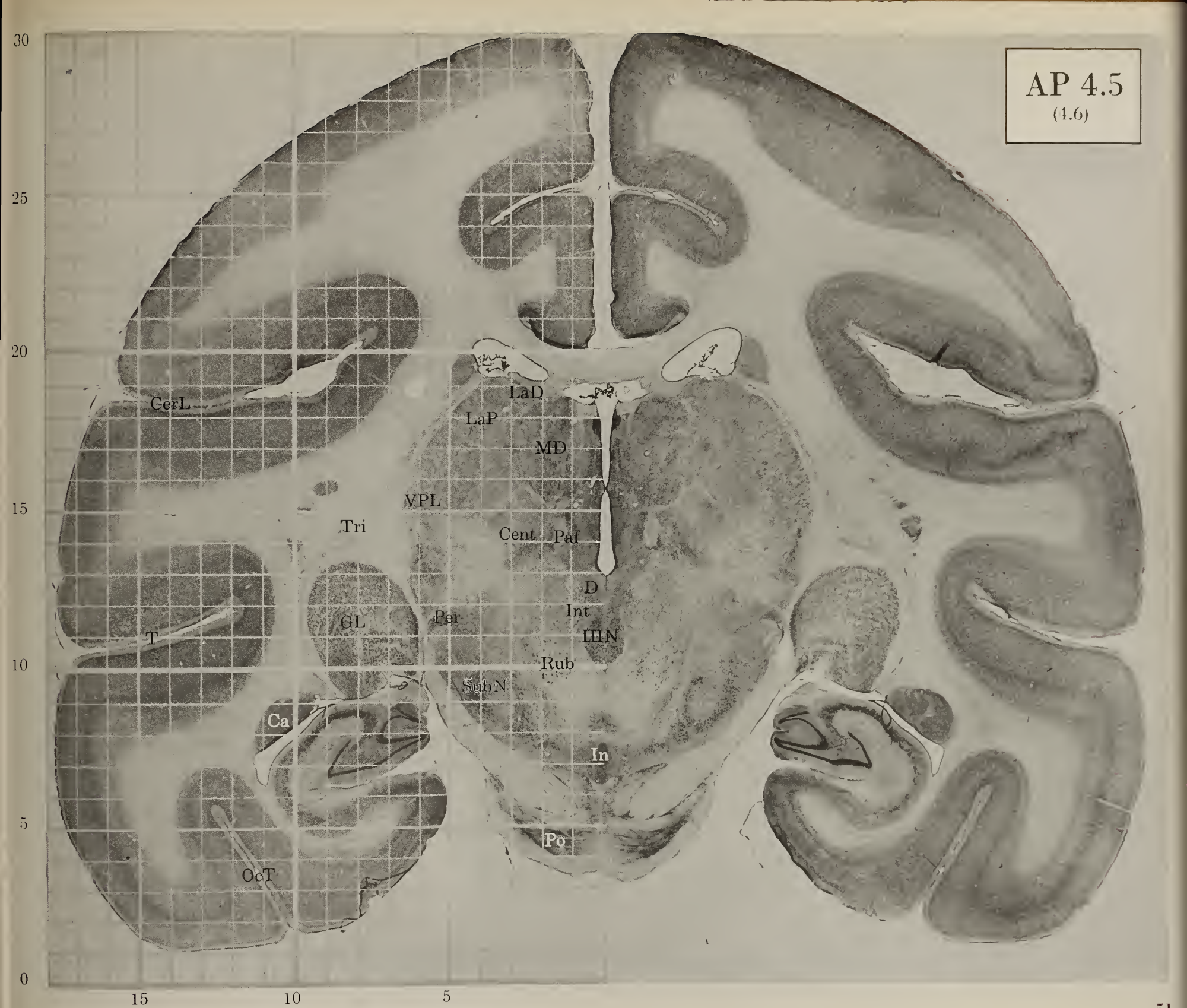
15
10
5
30


AP 4.5
(4.6)
30
25
20
15
10
5
0
15
10
5
GerL
LaD
LaP
MD
VPL
Tri
Cent
Paf
D
Int
IIIN
Rub
Per
GL
T
SubN
Ca
In
Po
OcT

AP 4.0
(4.0)
Cin
CC
StT
F
StM
HI
LeM
TeC
LeM
LM
StT
III
P
DBC
Alv
CSp
Cin
PMC
SSP
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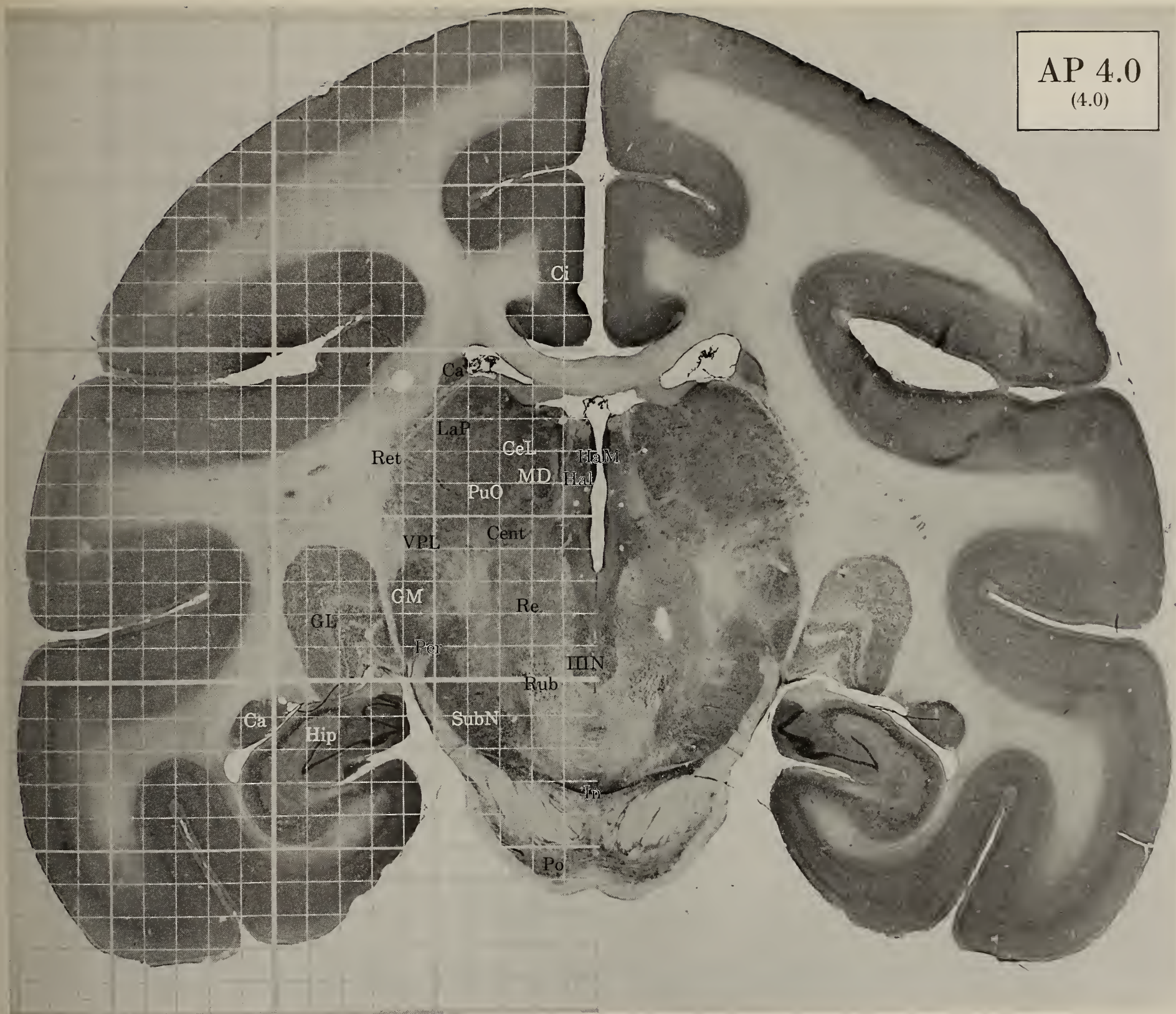
AP 4.0
(4.0)
Ci
Ca
LaP
Ret
CeL
HaM
MD
Hal
PuO
Cent
VPL
GM
Re
GL
Per
IIIN
Rub
Ca
Hip
SubN
Tn
Po
30
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20
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0
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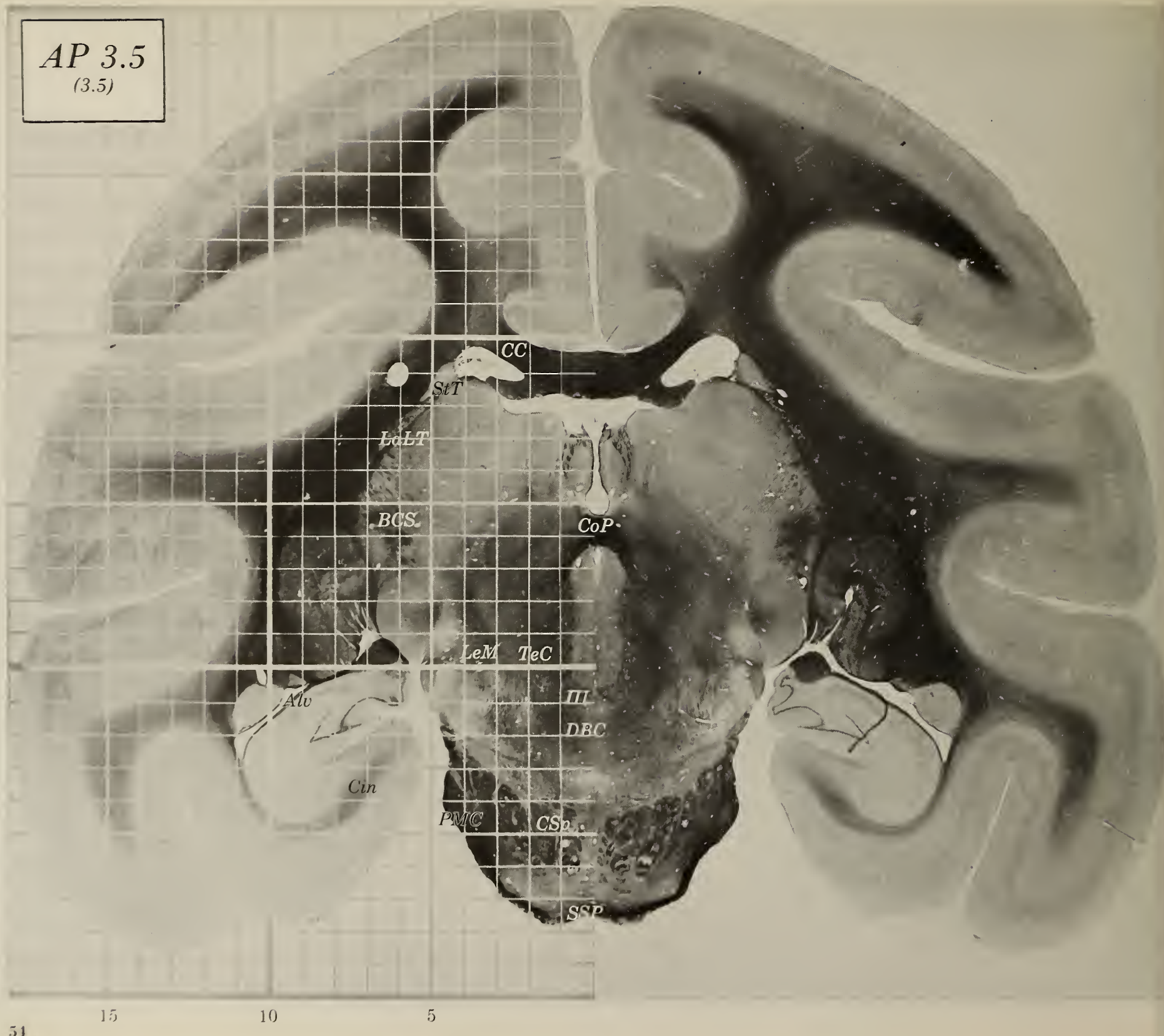
AP 3.5
(3.5)
CC
StT
LaLT
BCS
CoP
LeM
TeC
III
DBC
Alv
Cin
PMC
CSp
SSP
30
25
20
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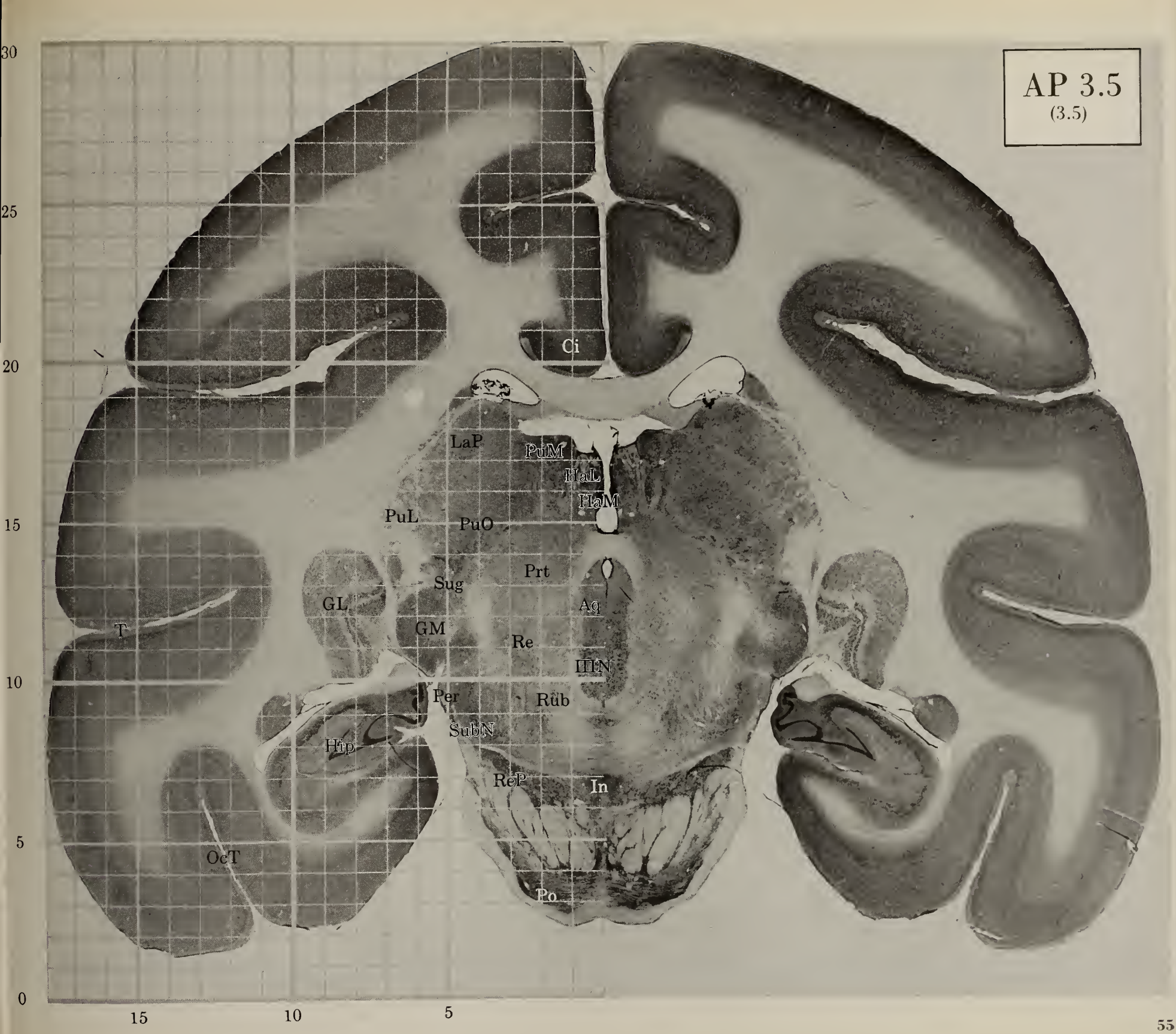
AP 3.5
(3.5)
Ci
LaP
PuM
HaL
HaM
PuL
PuO
Prt
Sug
GL
Aq
T
GM
Re
IIIN
Per
Rub
SubN
Hip
ReP
In
OcT
Po
30
25
20
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0
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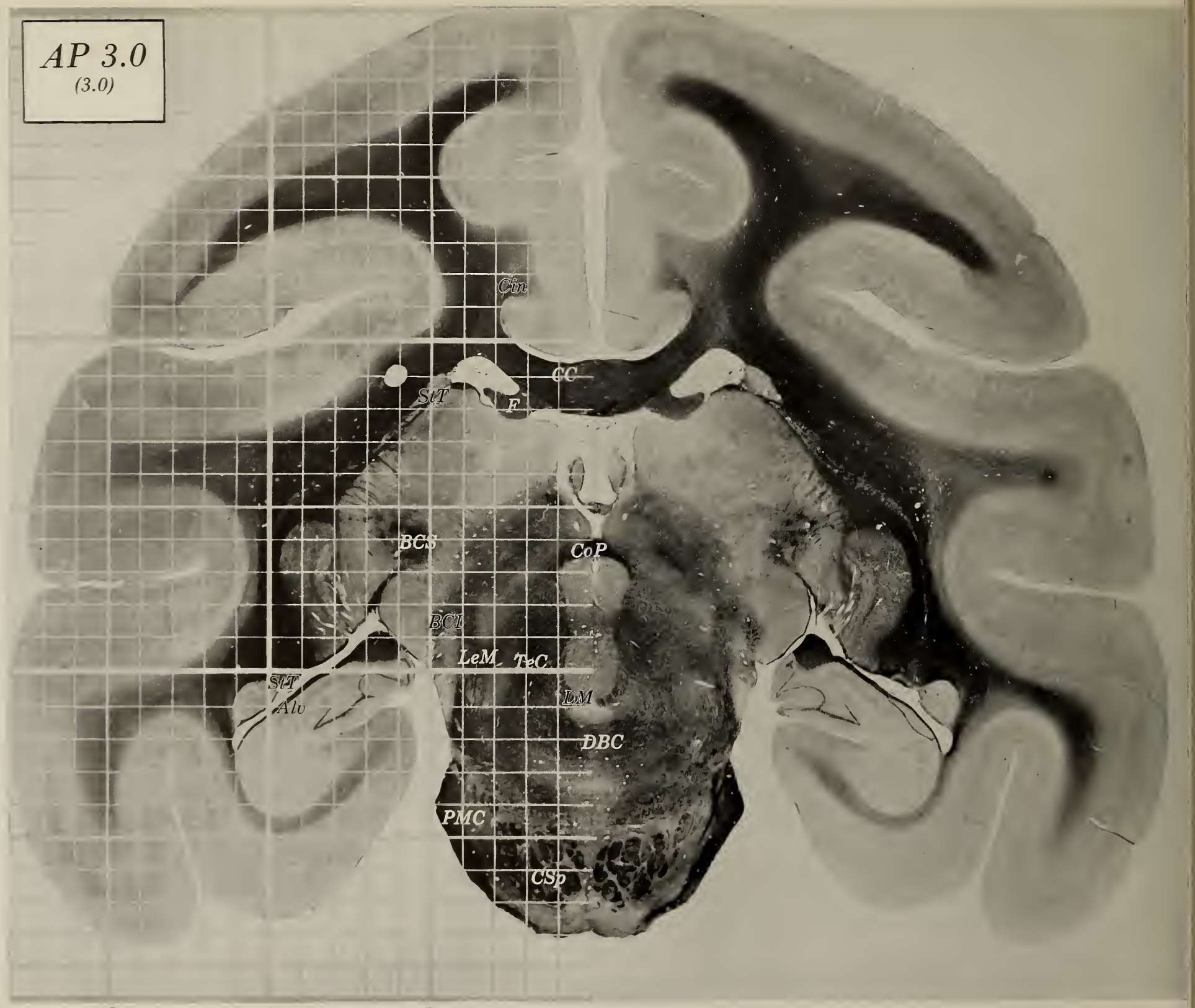
5


AP 3.0
(3.0)
Cin
CC
StT
F
BCS
CoP
BCI
LeM
TeC
StT
Alv
LM
DBC
PMC
CSp
30
25
20
15
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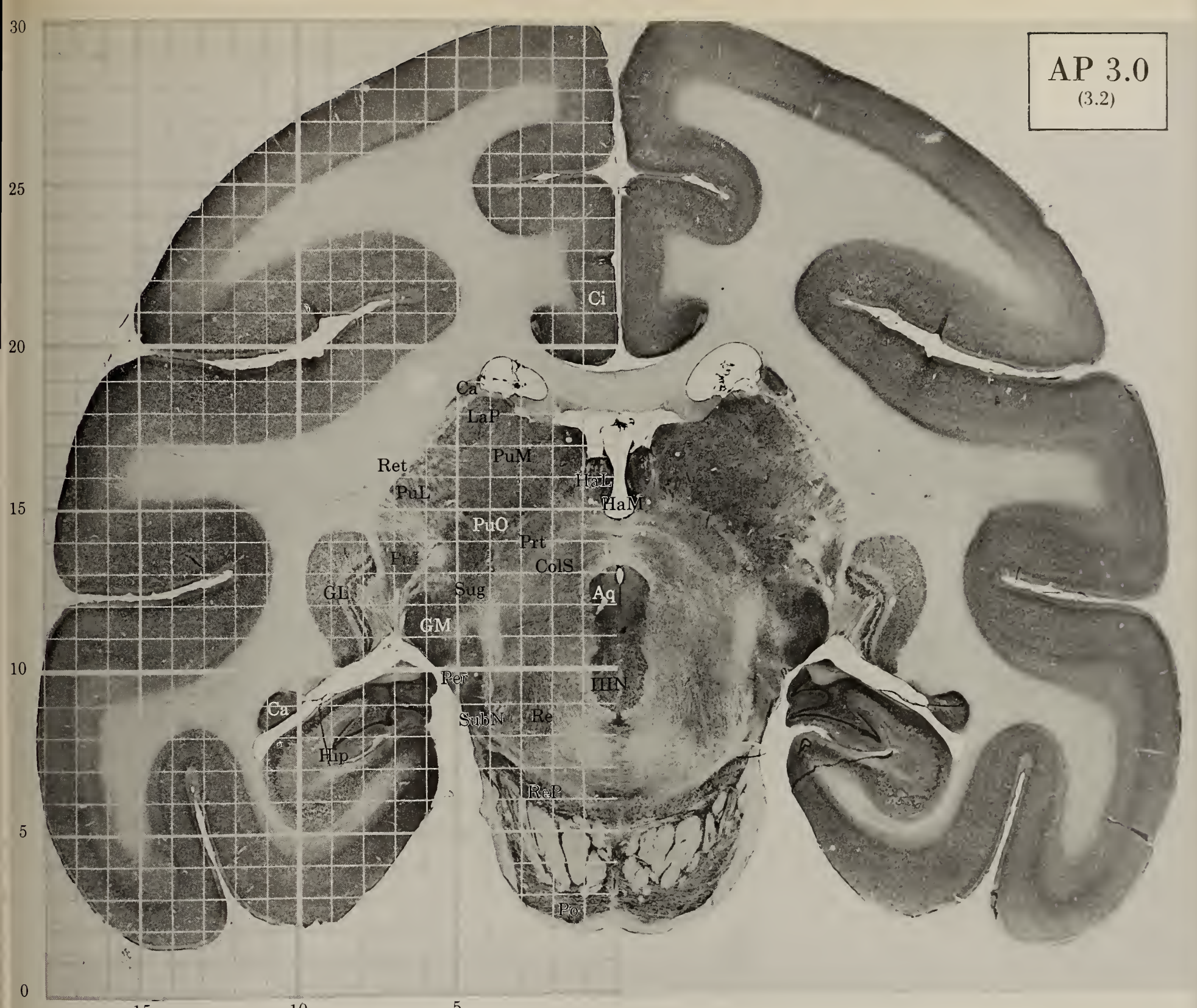
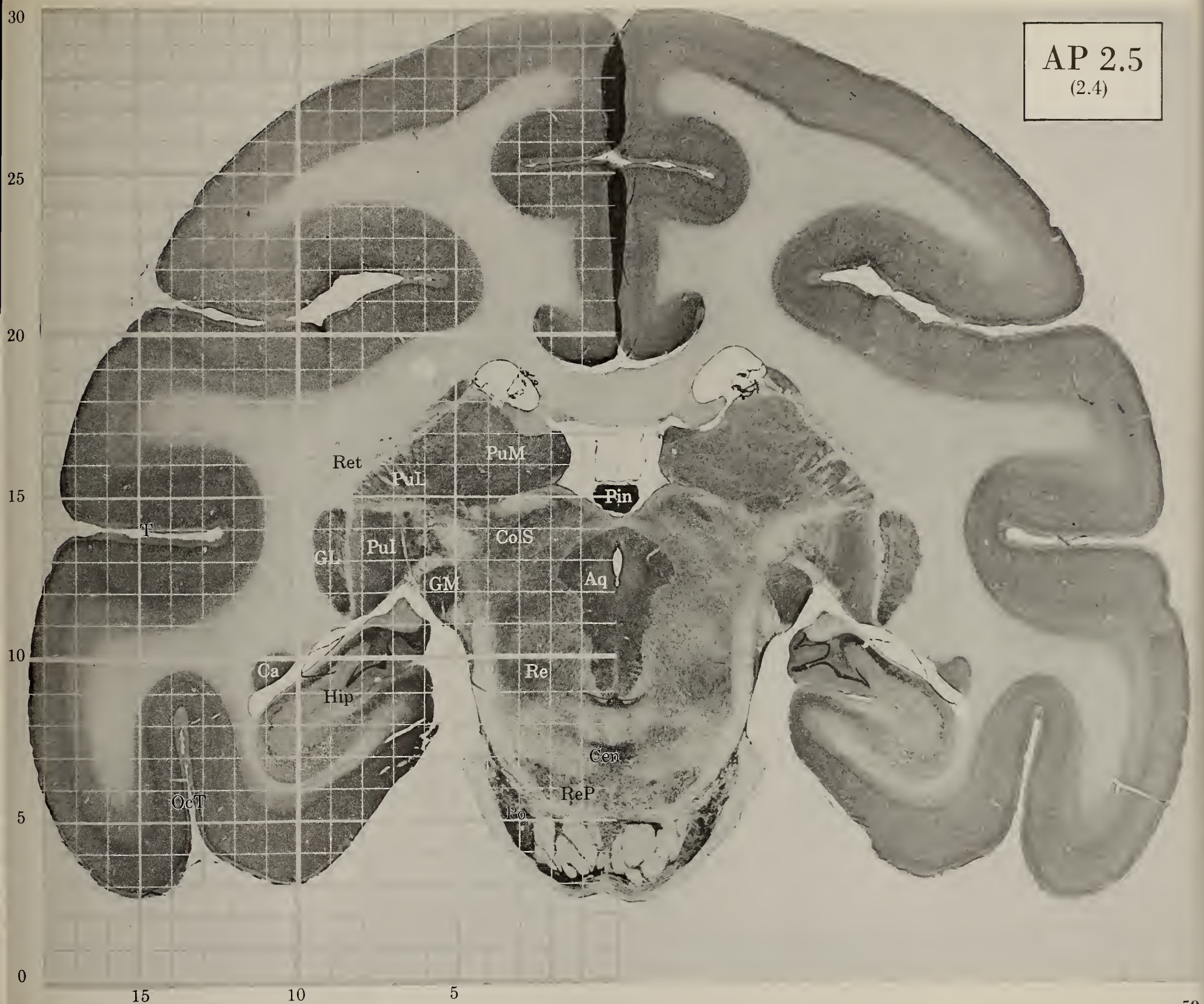
5
0
15
10
5


AP 3.0
(3.2)
Ci
Ca
LaP
PuM
Ret
PuL
HaL
HaM
PuO
Prt
ColS
Pul
GL
Sug
Aq
GM
Per
IIIN
Ca
SubN
Re
Hip
ReP
Po
30
25
20
15
10
5
0
15
10
5

AP 2.5
(2.4)
CC
StT
F
BCS
BCI
StT
Alv
Cin
TeC
LM
LeM
BBC
PMC
CSp
30
25
20
15
10
5
0
15
10
5


AP 2.5
(2.4)
Ret
PuL
PuM
Pin
T
GL
PuI
ColS
GM
Aq
Ca
Re
Hip
Cen
RePo
OcT
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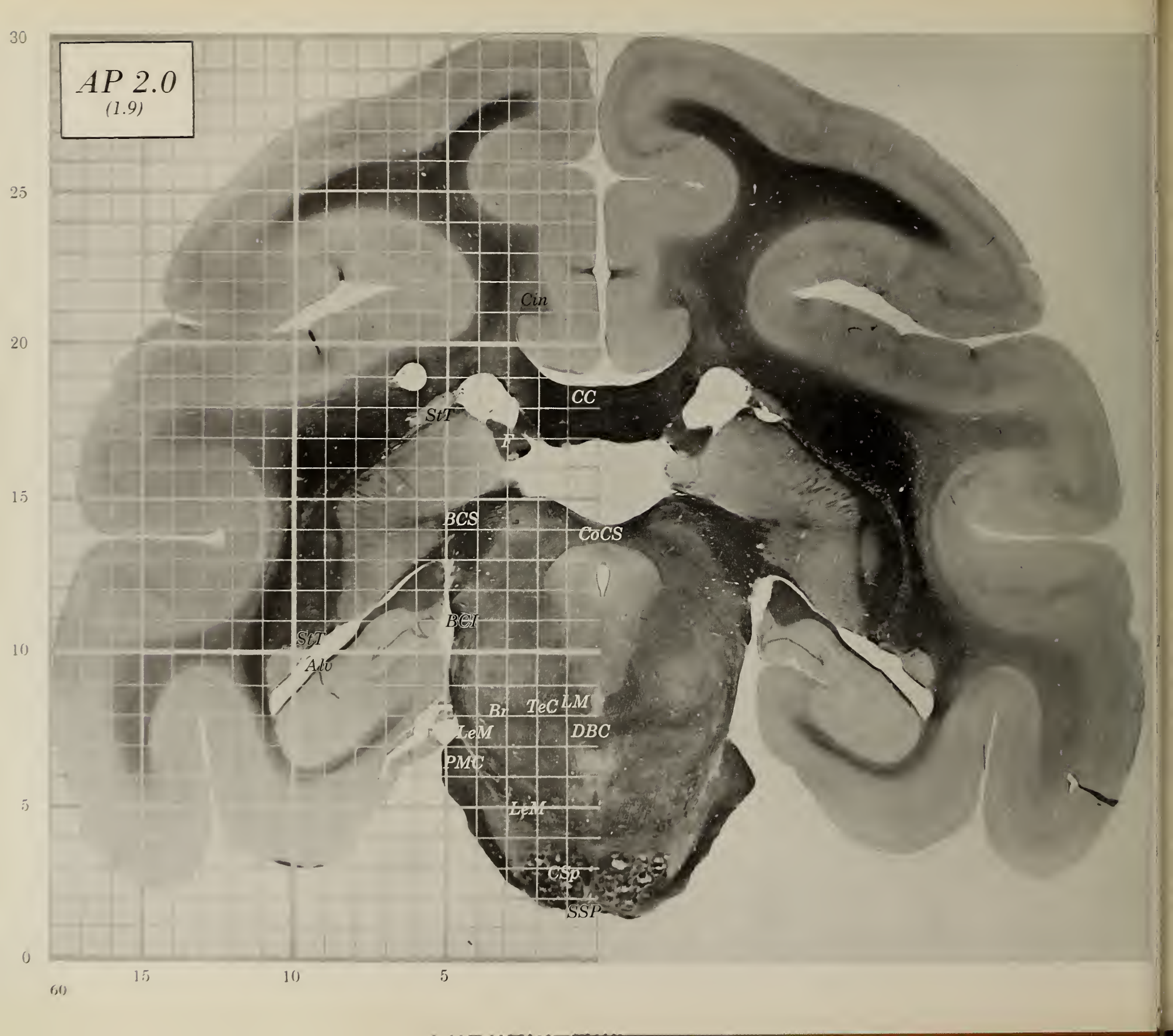
AP 2.0
(1.9)
Cin
CC
StT
F
BCS
CoCS
BCI
StT
Alv
Bs
TeC
LM
LeM
DBC
PMC
LeM
CSp
SSP
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15
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5
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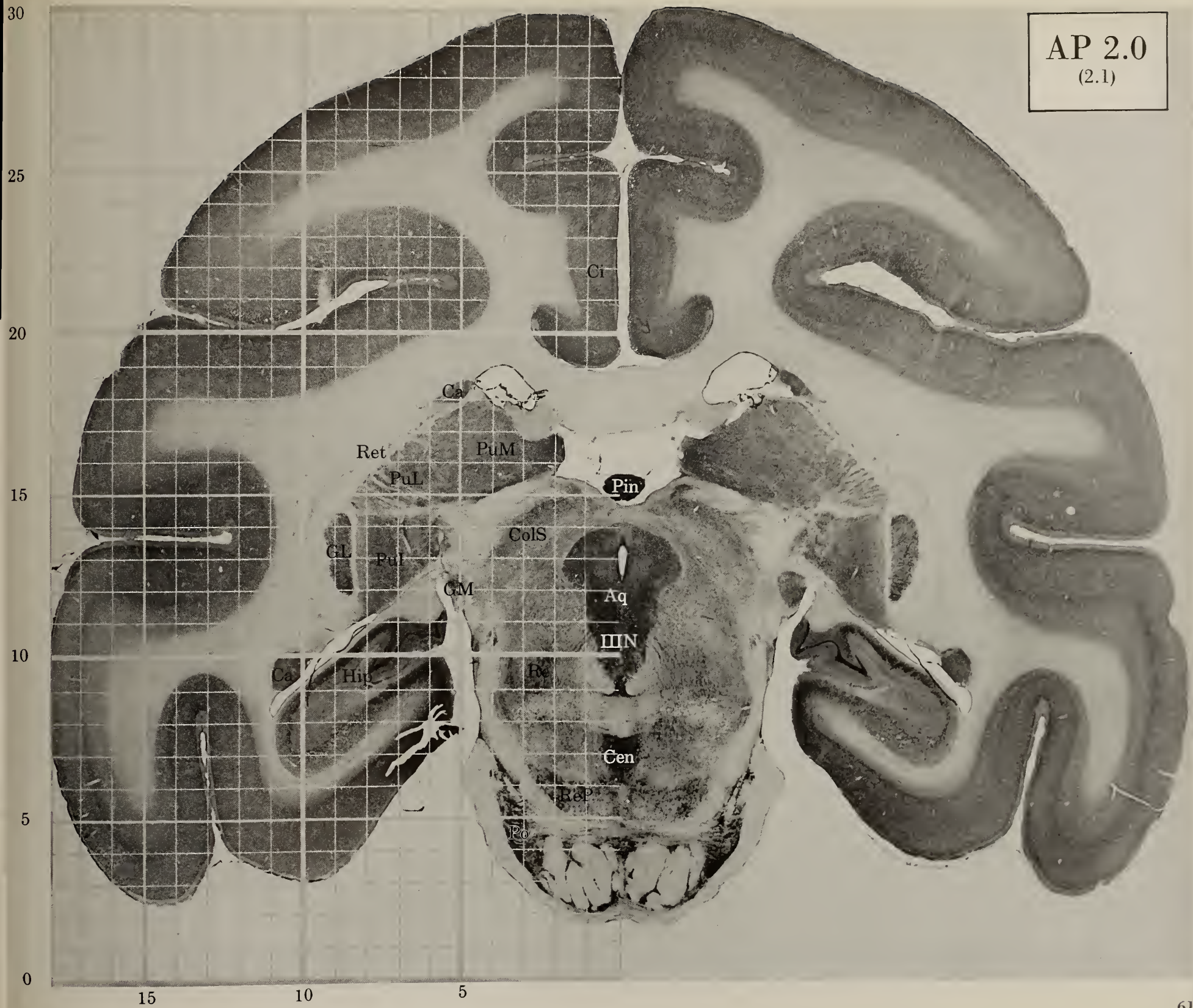
5
60


AP 2.0
(2.1)
Ci
Ca
Ret
PuM
PuL
Pin
ColS
GL
Pul
GM
Aq
IIIN
Ca
Hip
Re
Cen
ReP
Po
30
25
20
15
10
5
0
15
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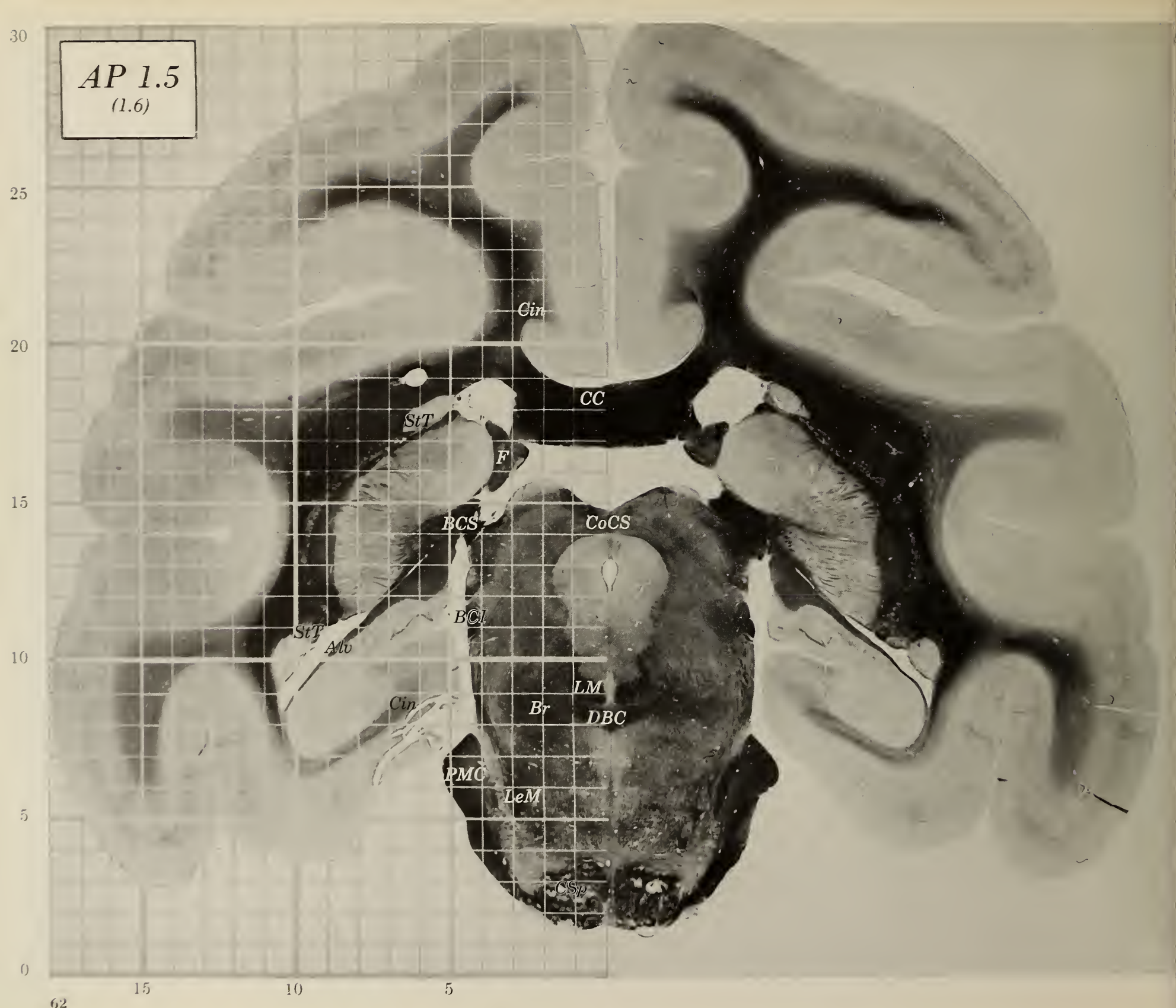
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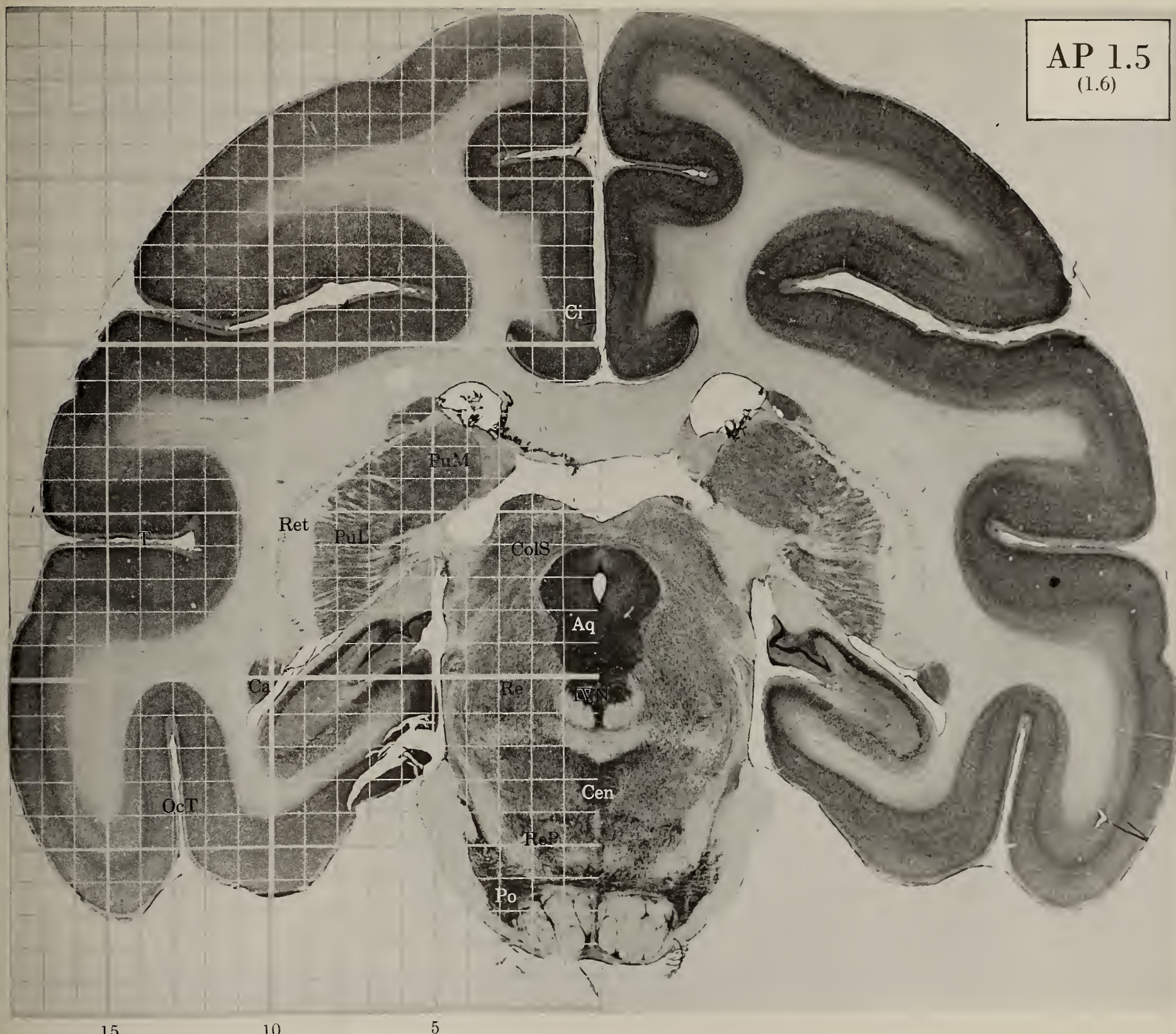
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F
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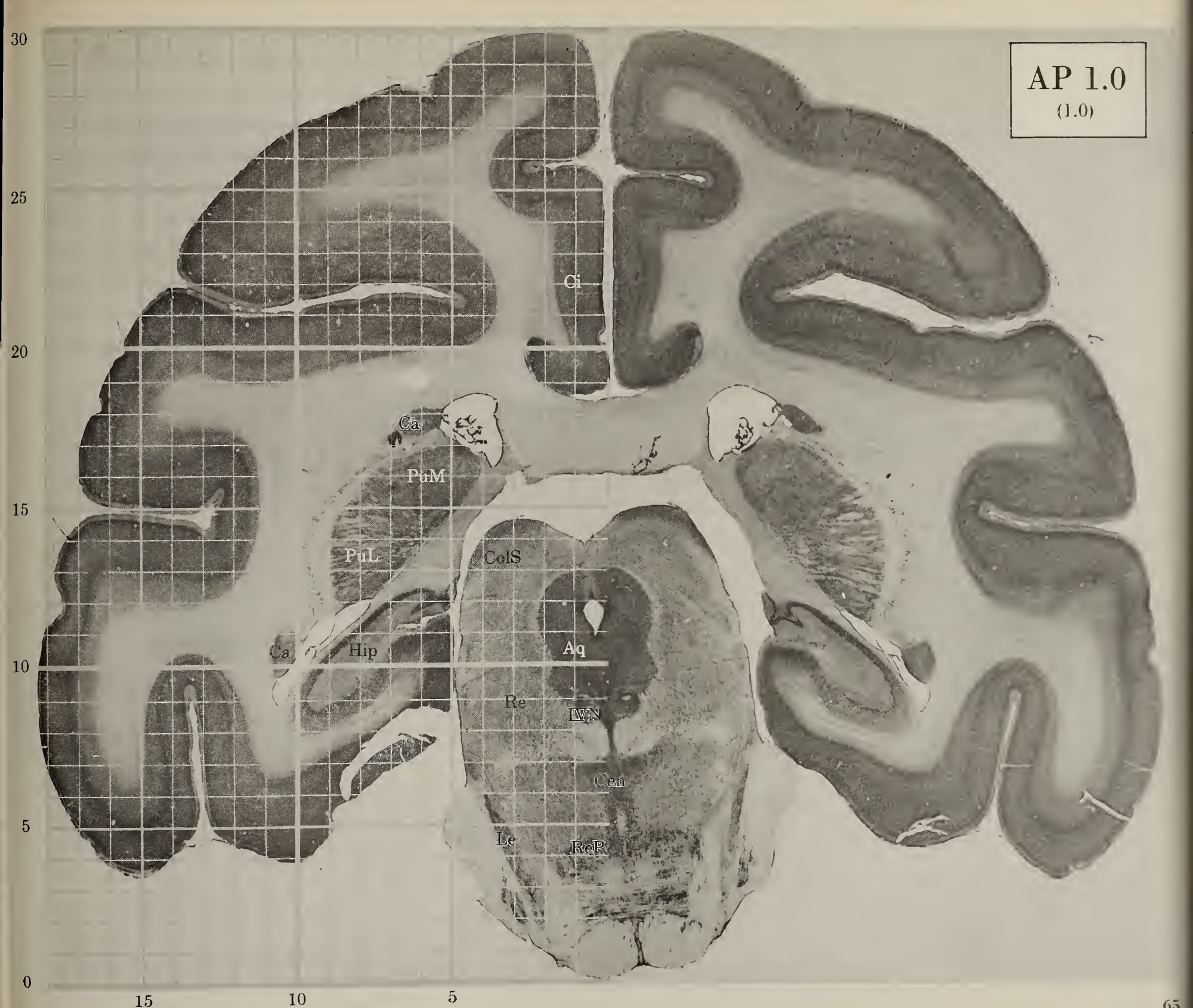
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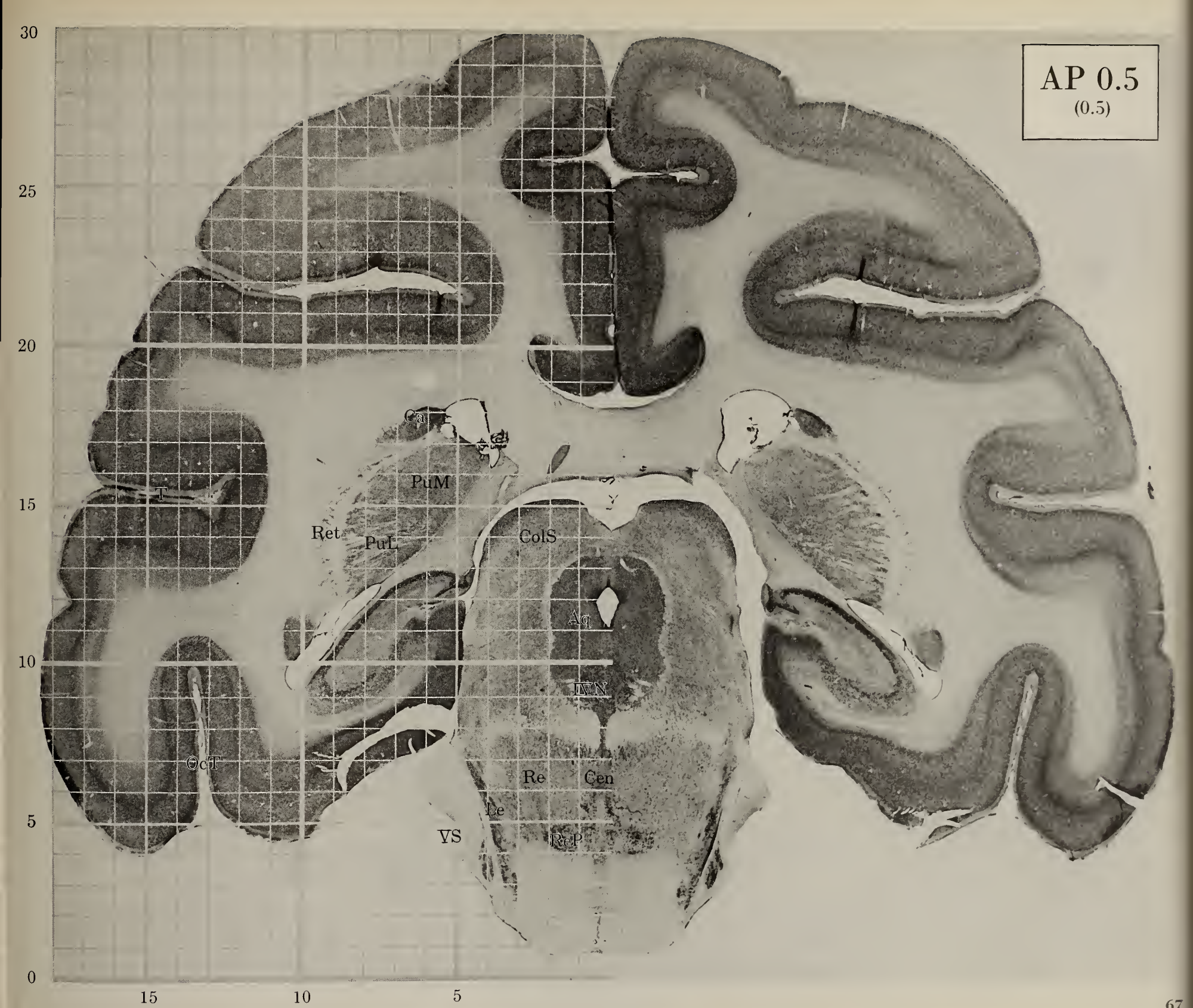
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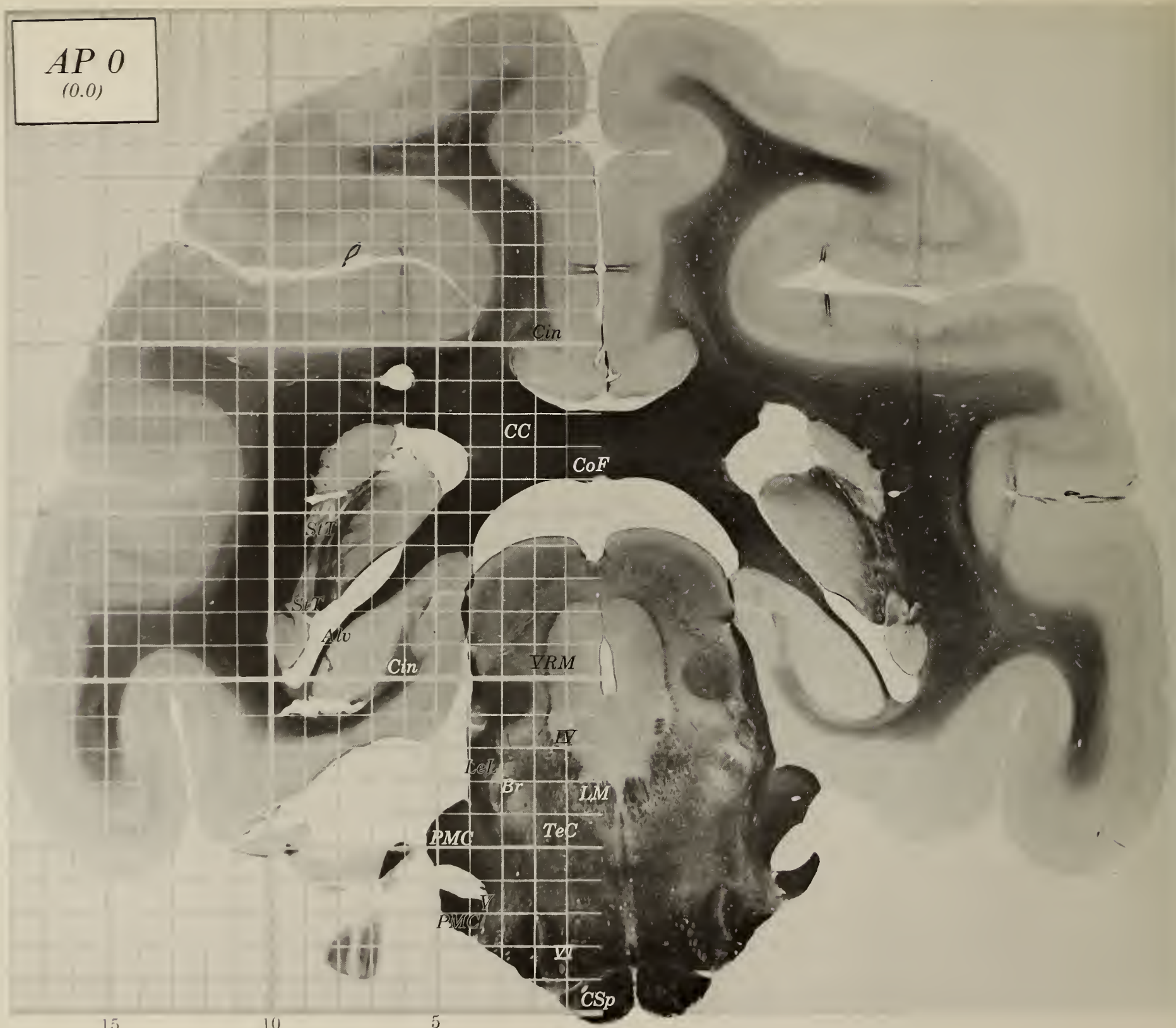
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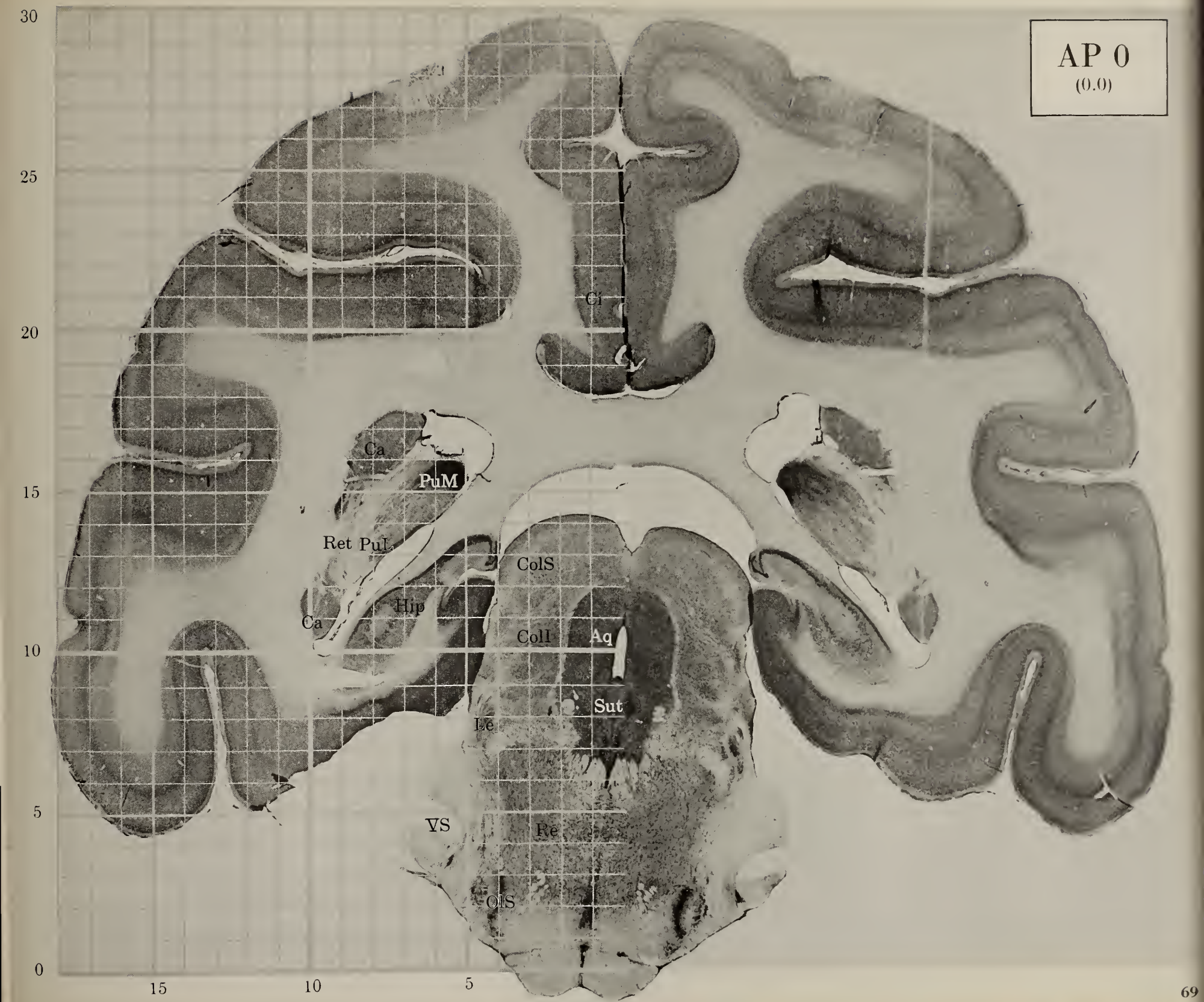
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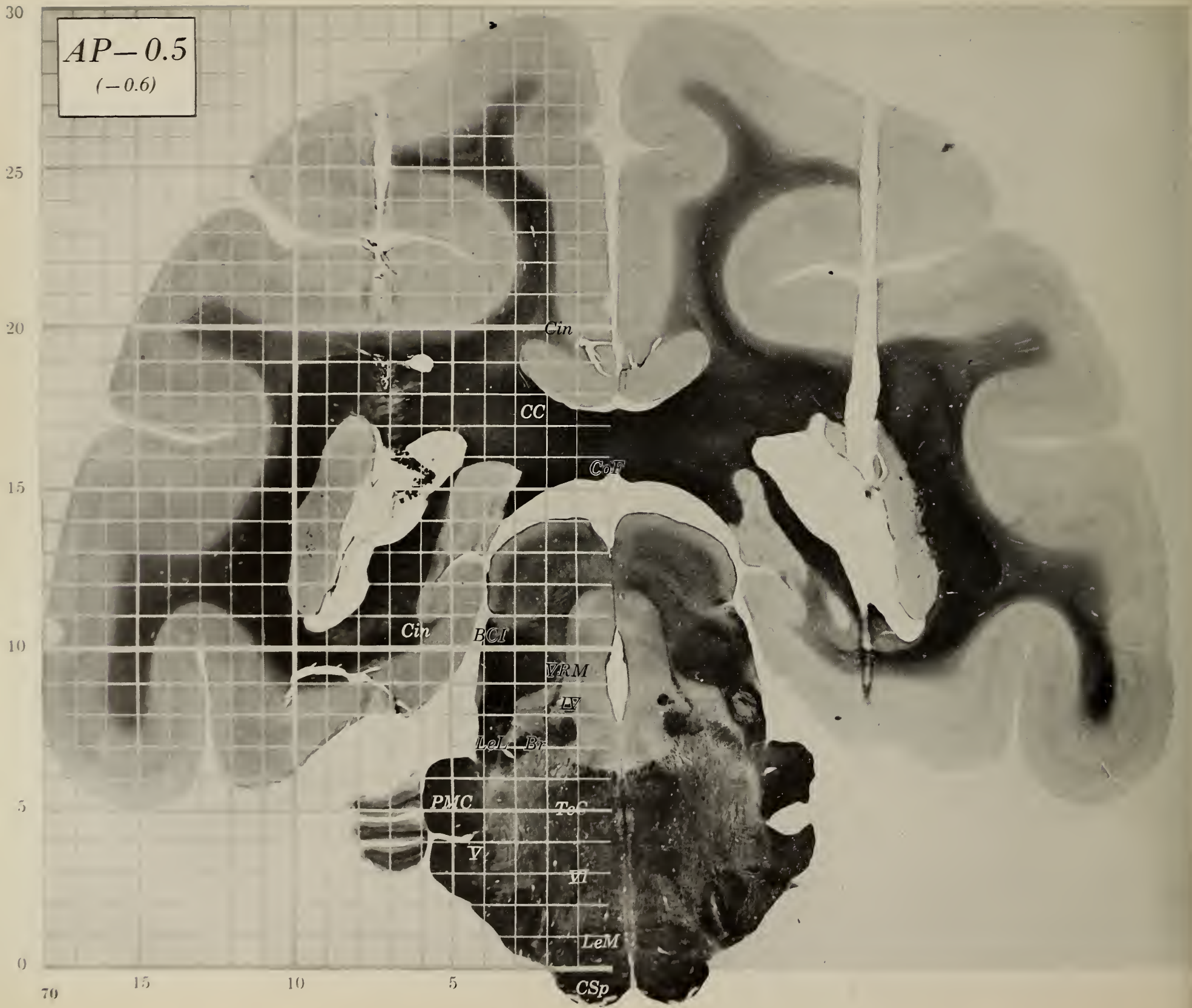
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CSp
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5
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(– 0.6)
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Ca
Hip
ColS
ColI
Aq
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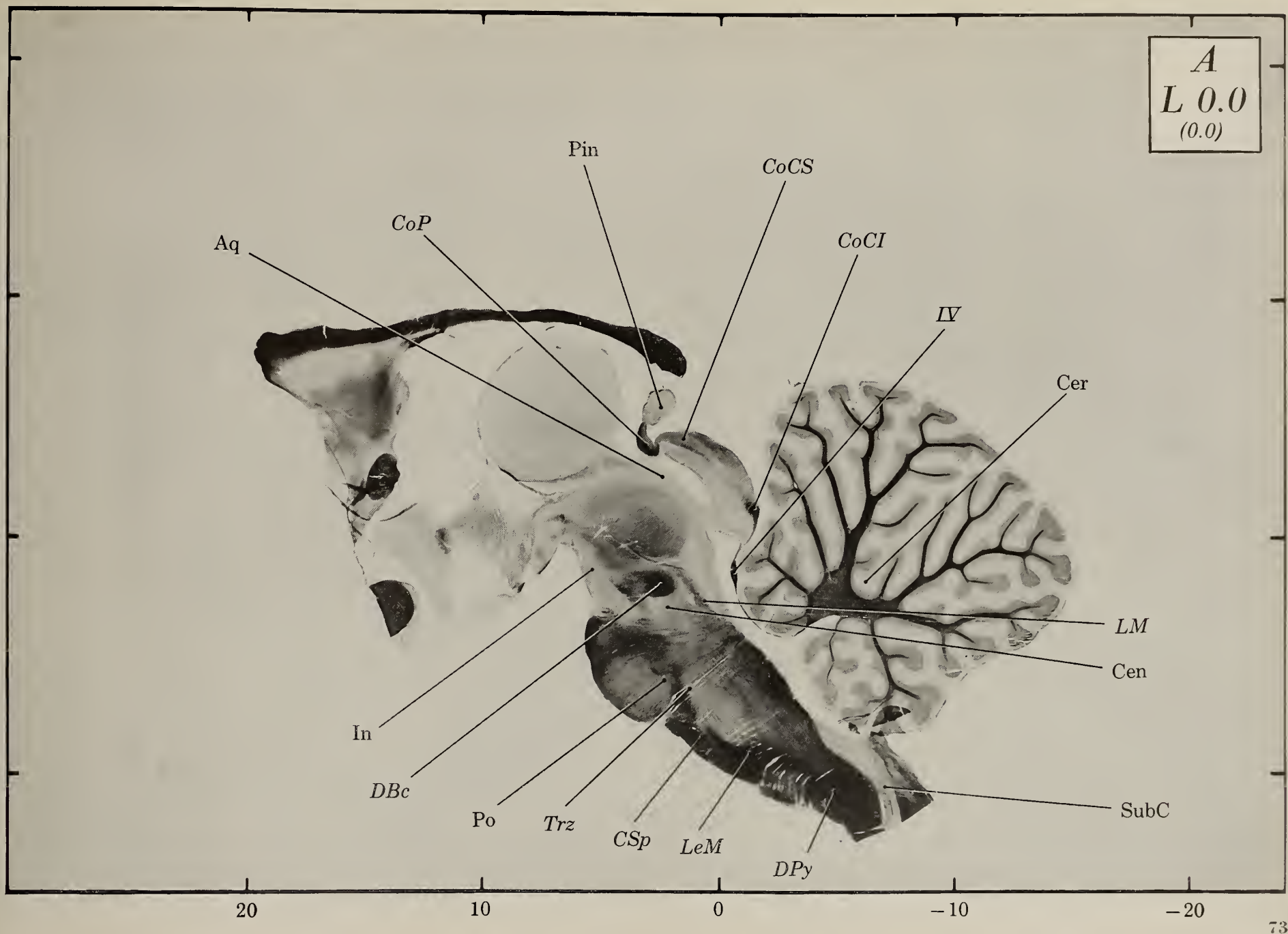
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SubC
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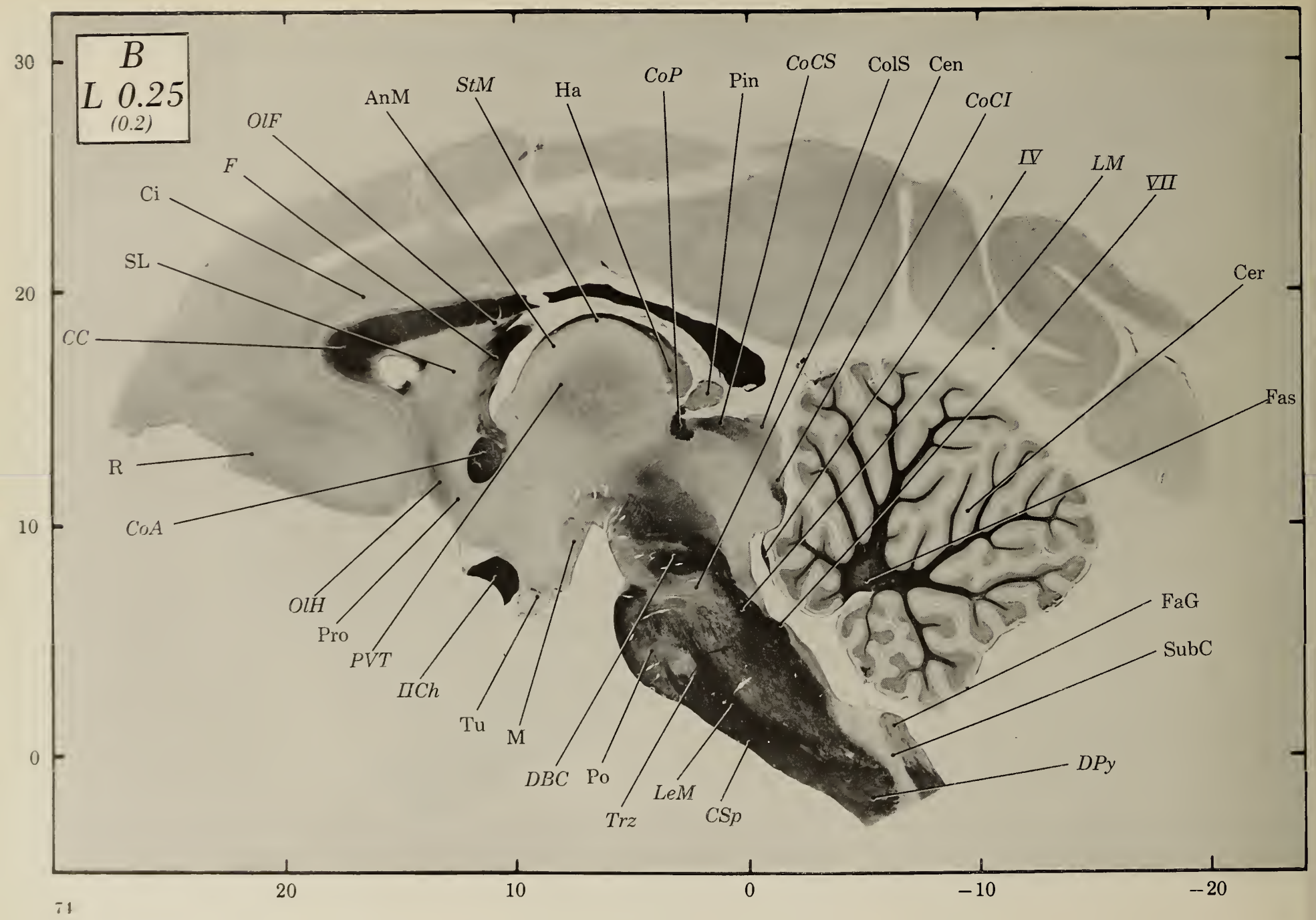
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Fas
FaG
SubC
DPy
OlF
F
Ci
SL
CC
R
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OlH
Pro
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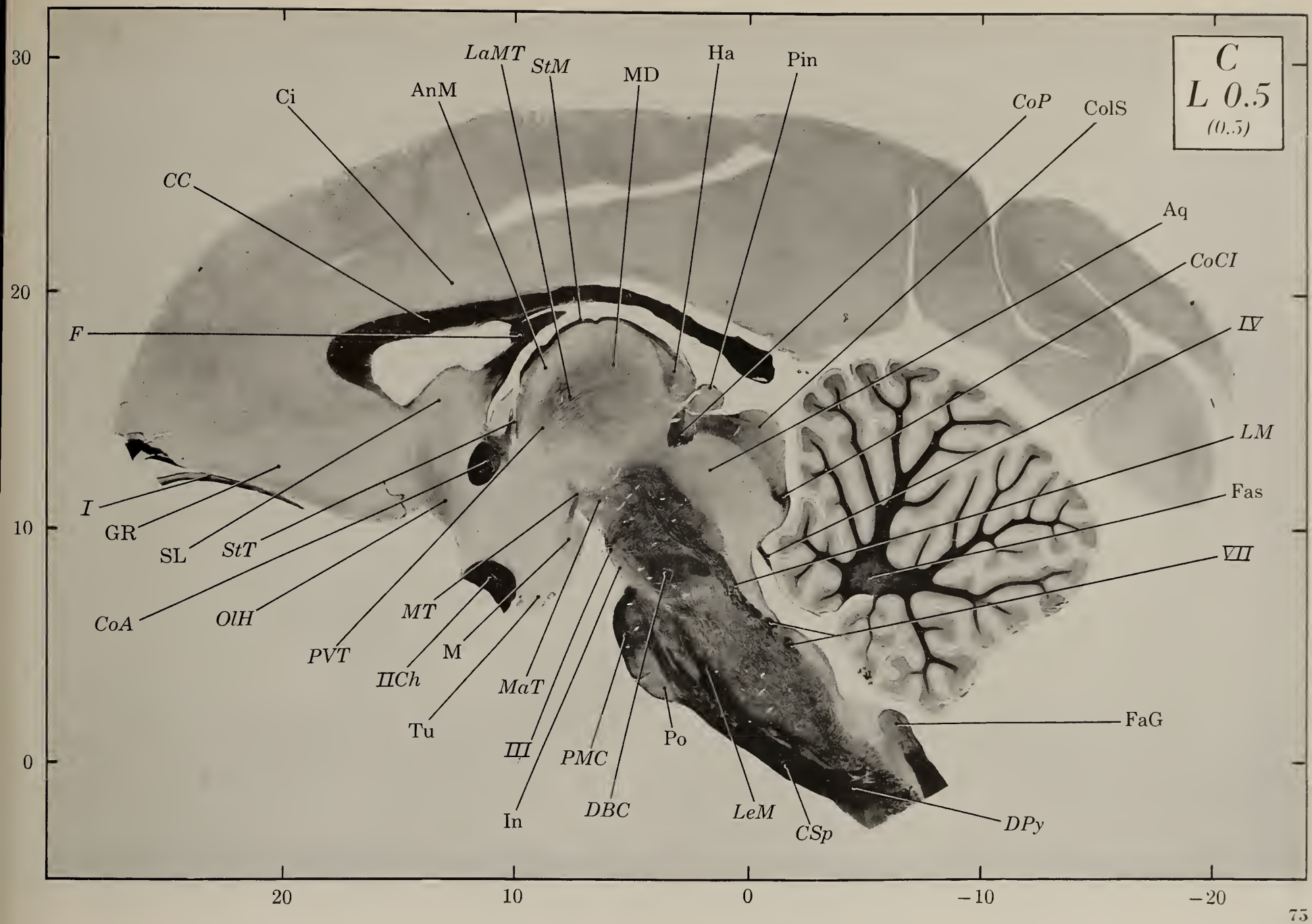
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LM
Fas
VII
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GR
SL
StT
CoA
OlH
MT
PVT
IICh
M
MaT
Tu
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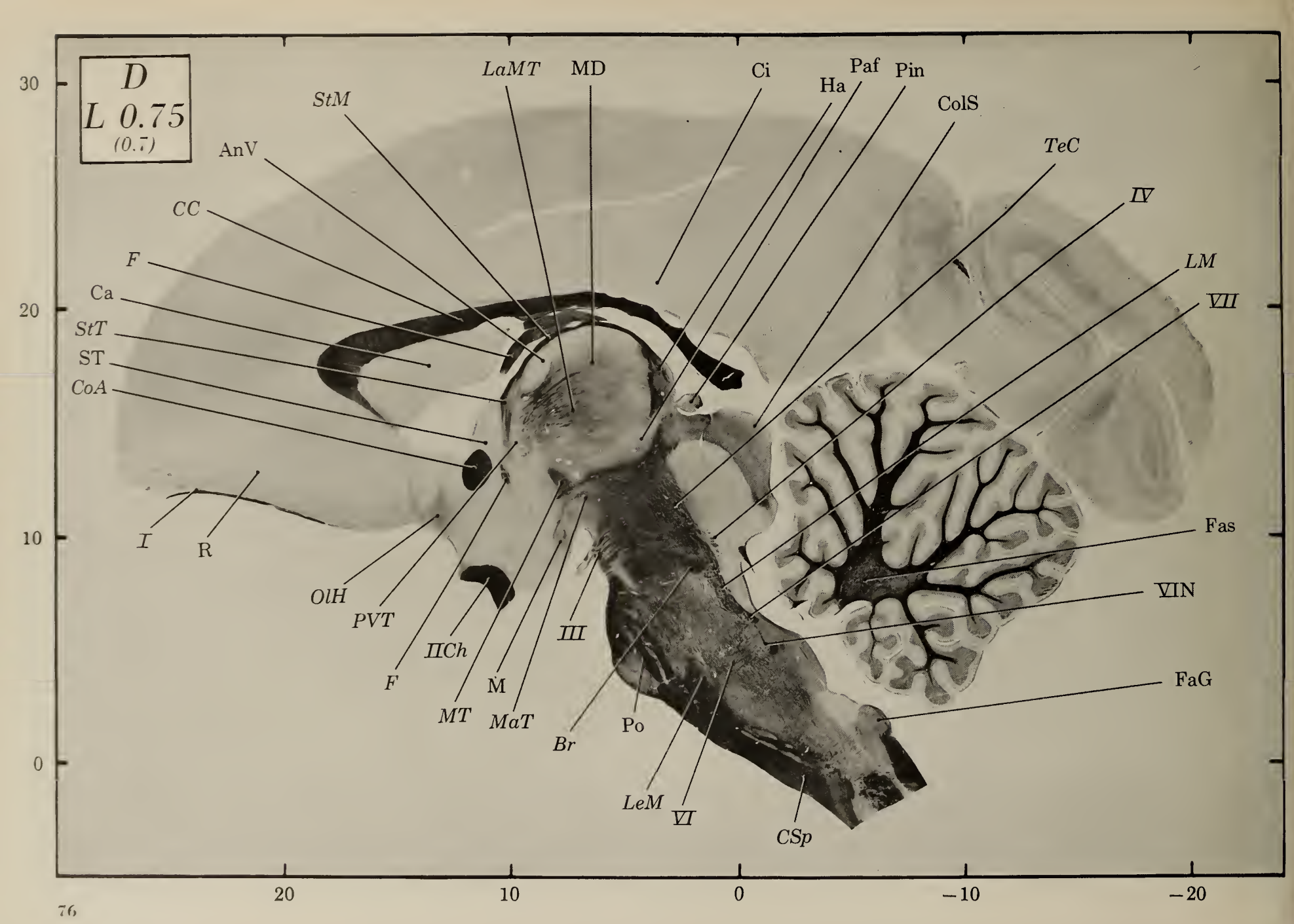
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CC
F
Ca
StT
ST
CoA
I
R
OlH
PVT
IICh
F
MT
M
MaT
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Po
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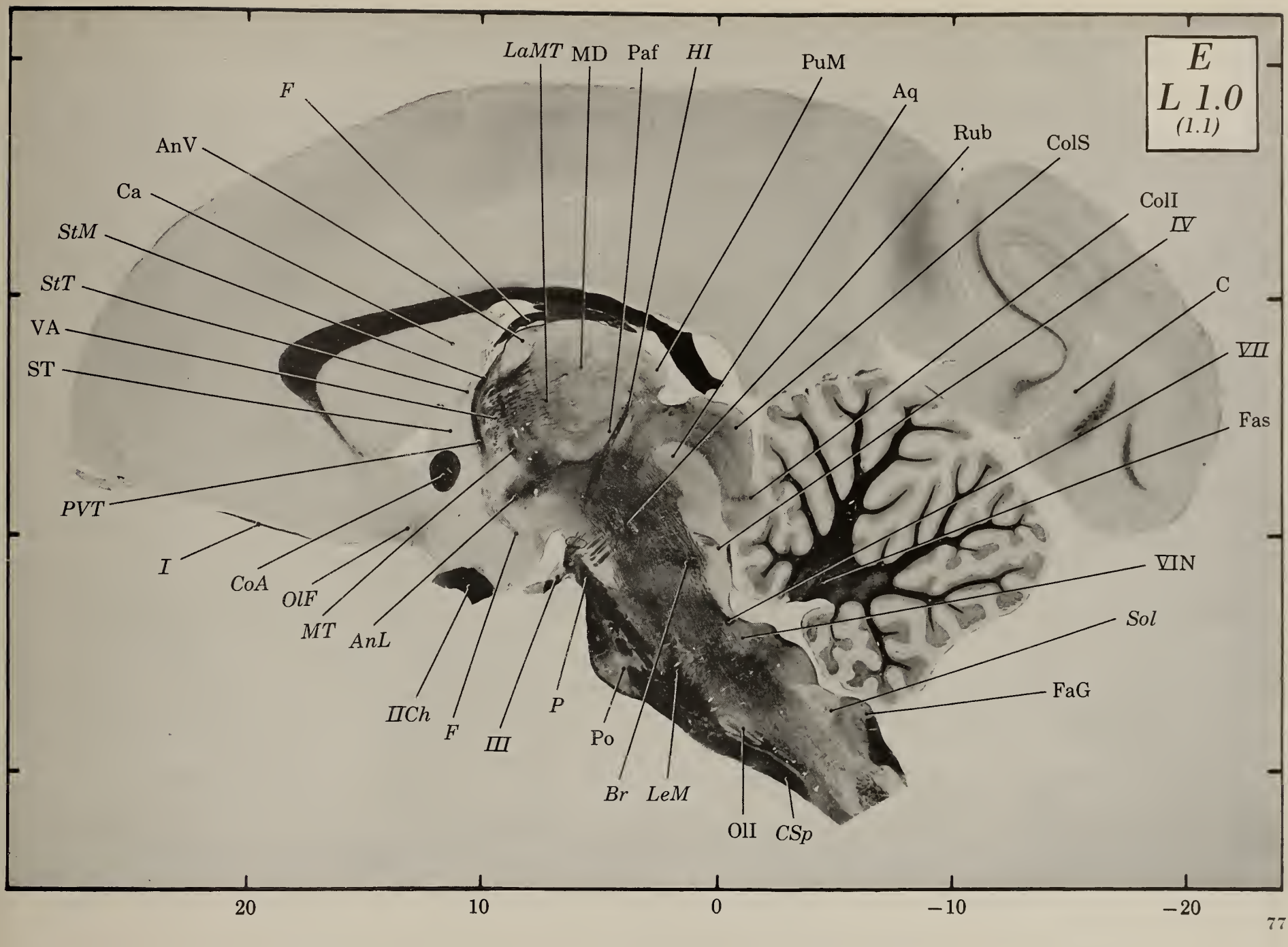
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MD
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HI
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Rub
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Fas
F
AnV
Ca
StM
StT
VA
ST
PVT
I
CoA
OlF
MT
AnL
IICh
F
III
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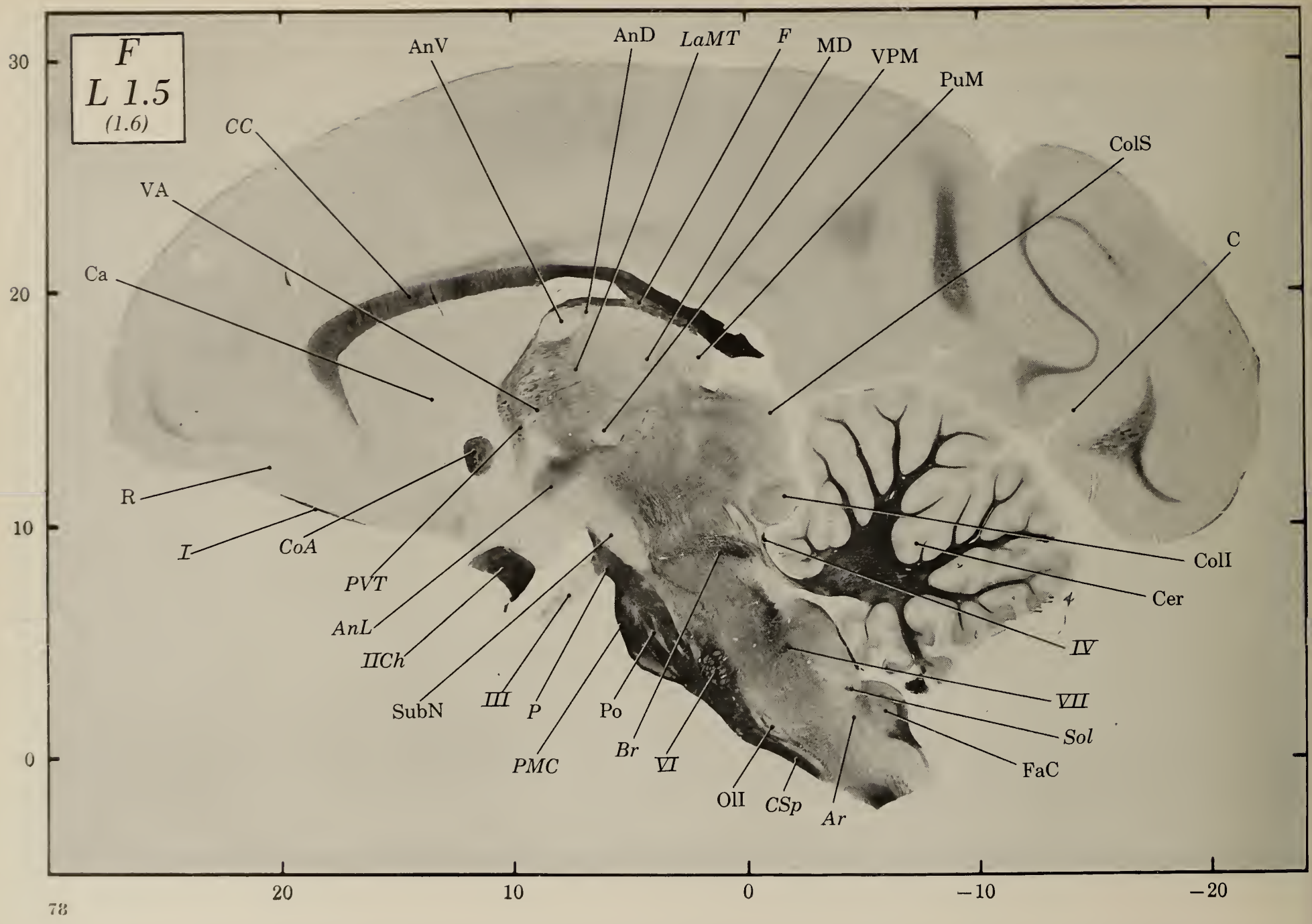
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AnD
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CC
ColS
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C
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R
I
CoA
PVT
AnL
IICh
SubN
III
P
Po
Br
VI
PMC
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Cer
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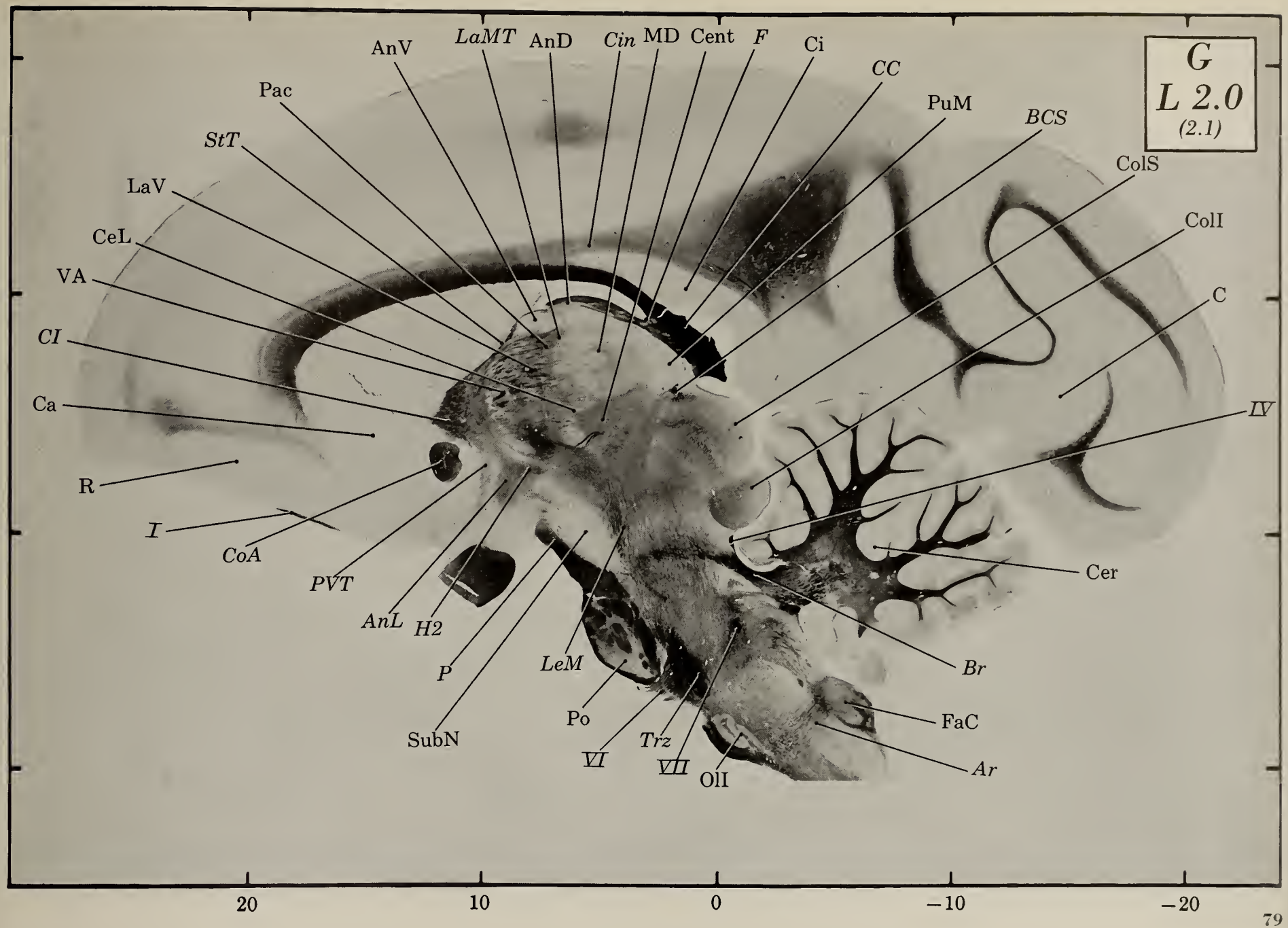
G
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LaMT
AnD
Cin
MD
Cent
F
Ci
CC
PuM
BCS
ColS
ColI
C
IV
Cer
Br
FaC
Ar
OlI
VII
VI
Trz
Po
LeM
SubN
P
H2
AnL
PVT
CoA
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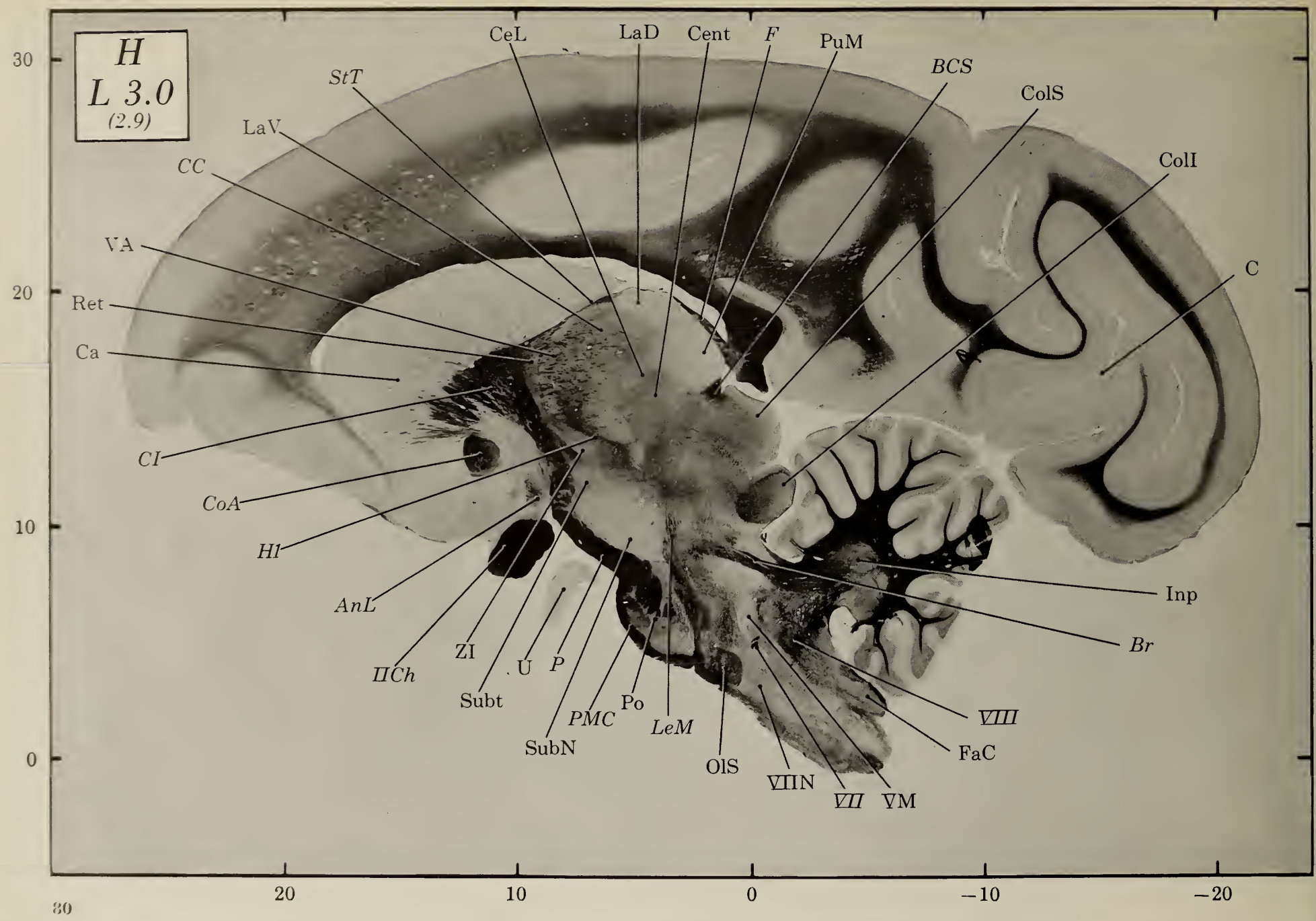
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(2.9)
CeL
LaD
Cent
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PuM
BCS
ColS
ColI
C
StT
LaV
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VA
Ret
Ca
CI
CoA
Hl
AnL
IICh
ZI
U
P
Subt
PMC
Po
LeM
SubN
OlS
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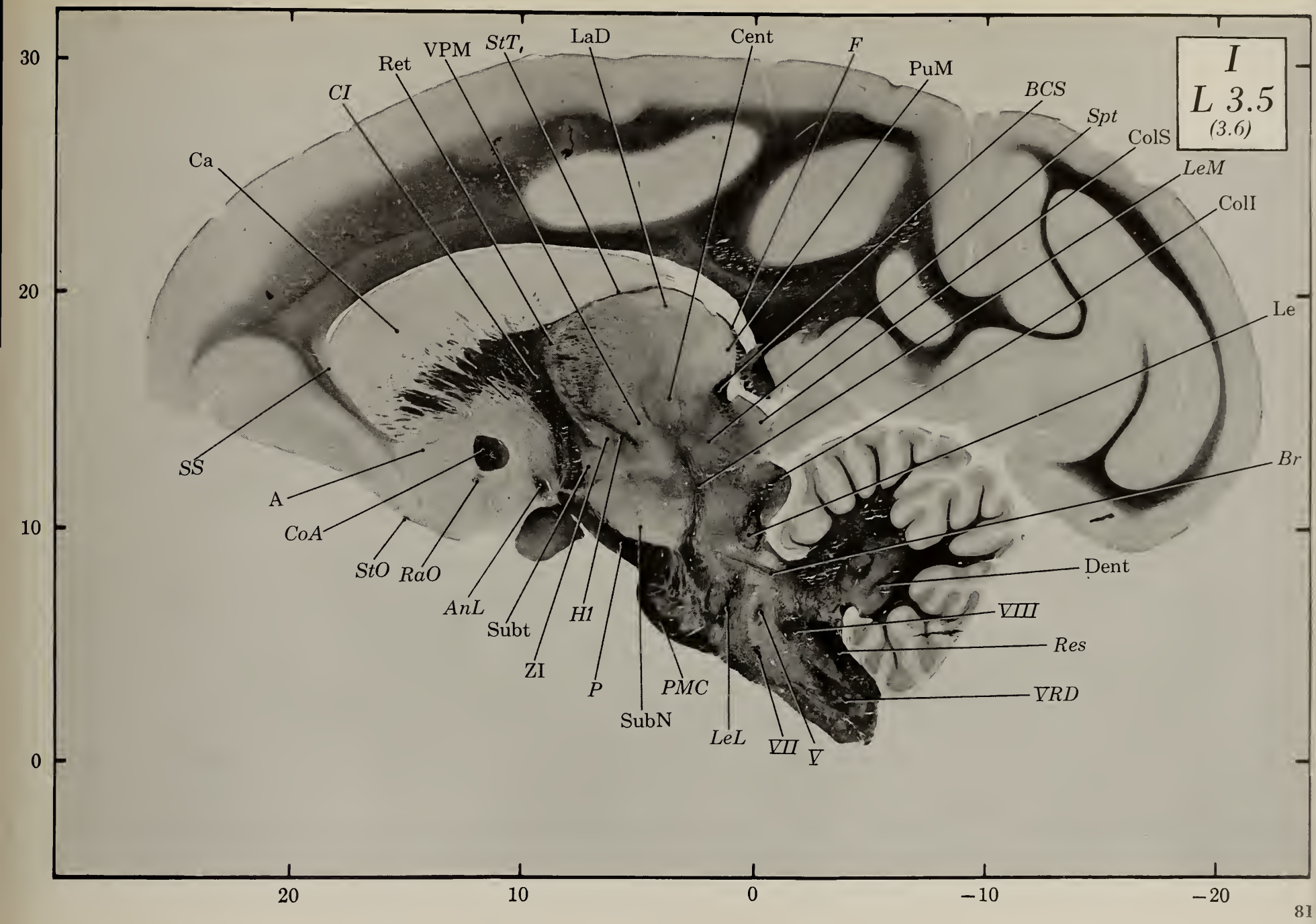
I
L 3.5
(3.6)
Ca
CI
Ret
VPM
StT
LaD
Cent
F
PuM
BCS
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LeM
ColI
Le
Br
Dent
VIII
Res
VRD
V
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LeL
SubN
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P
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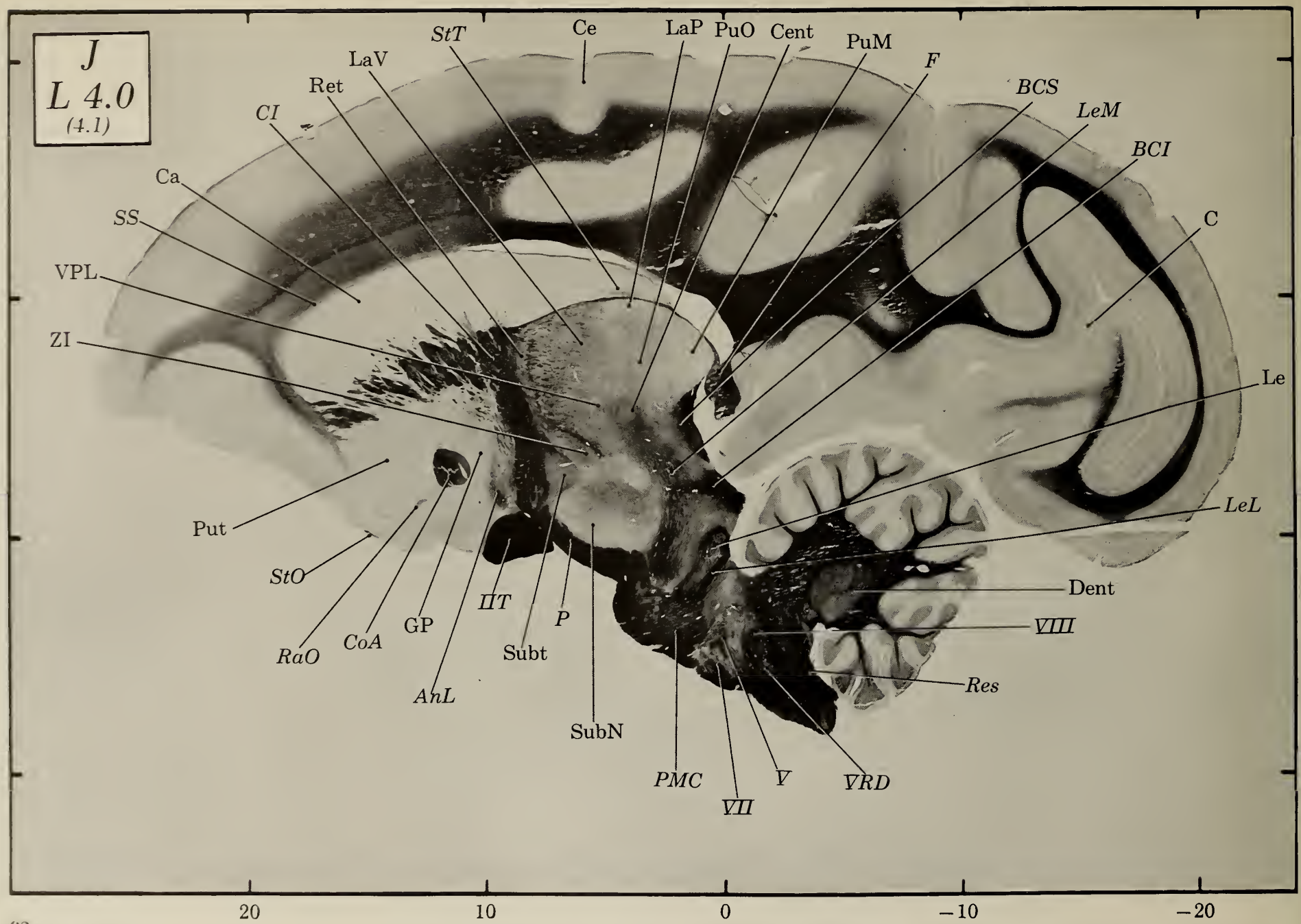
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(4.1)
StT
Ce
LaP
PuO
Cent
PuM
F
LaV
Ret
CI
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BCI
Ca
SS
C
VPL
ZI
Le
LeL
Put
StO
Dent
VIII
IIT
P
GP
CoA
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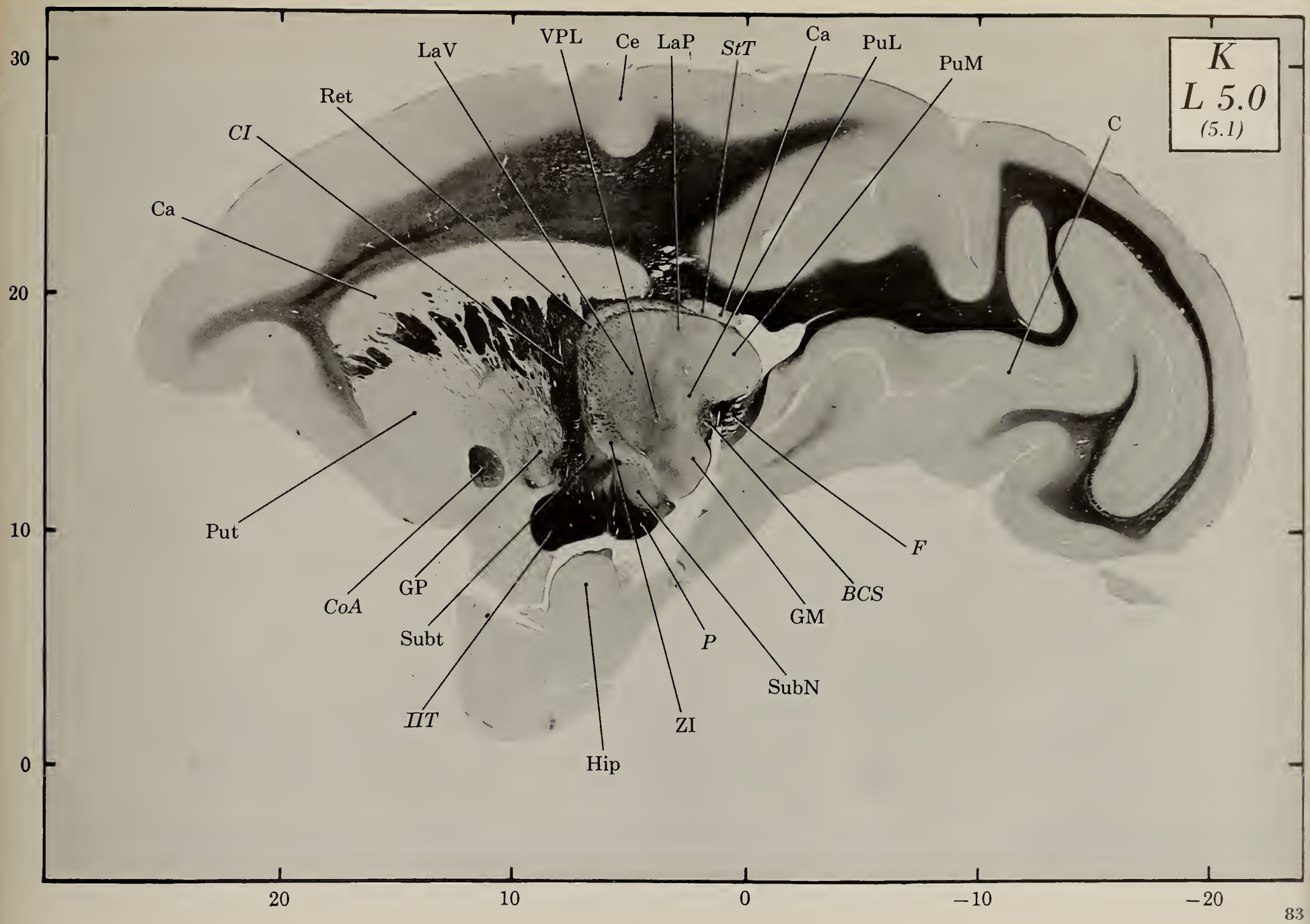
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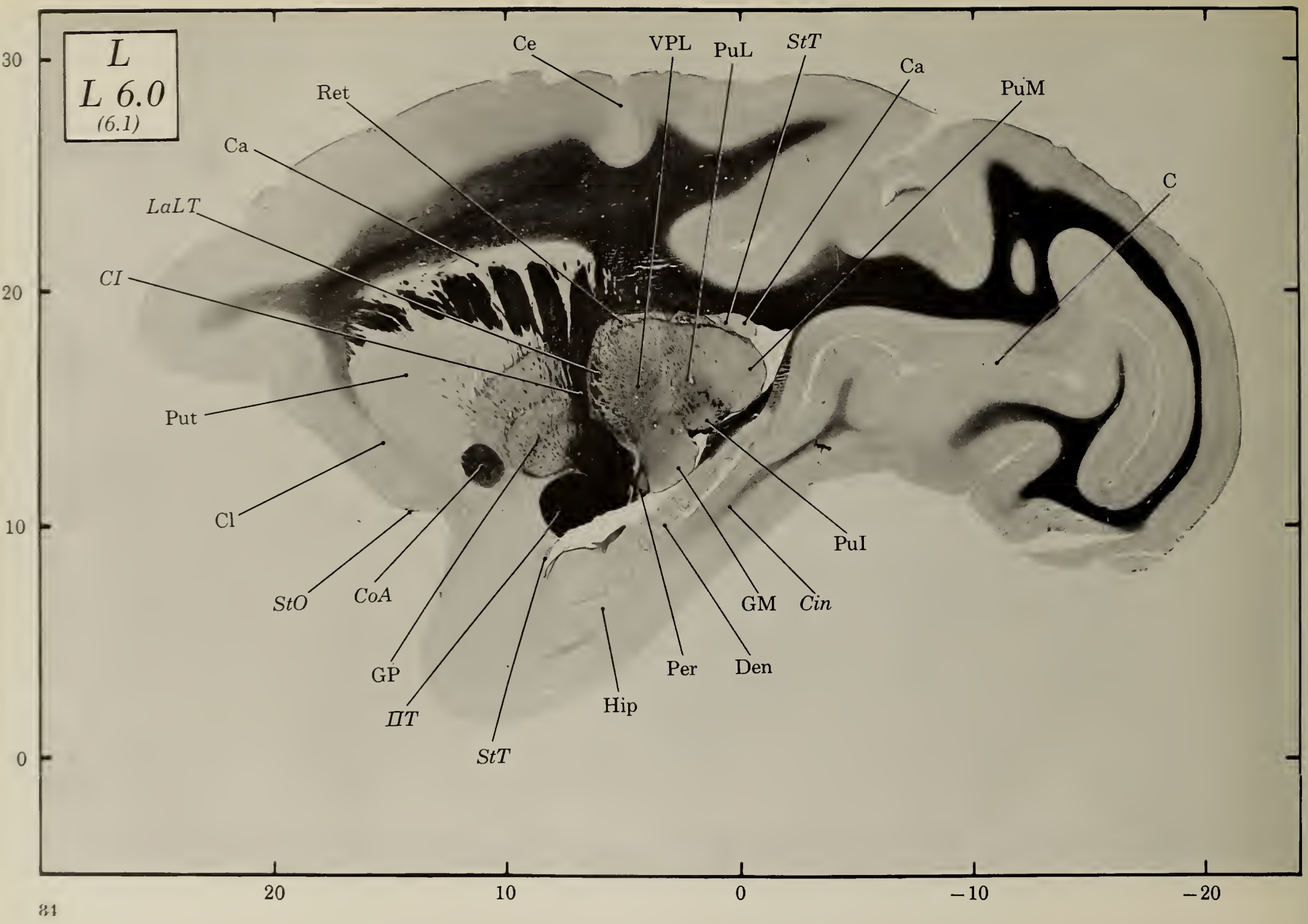
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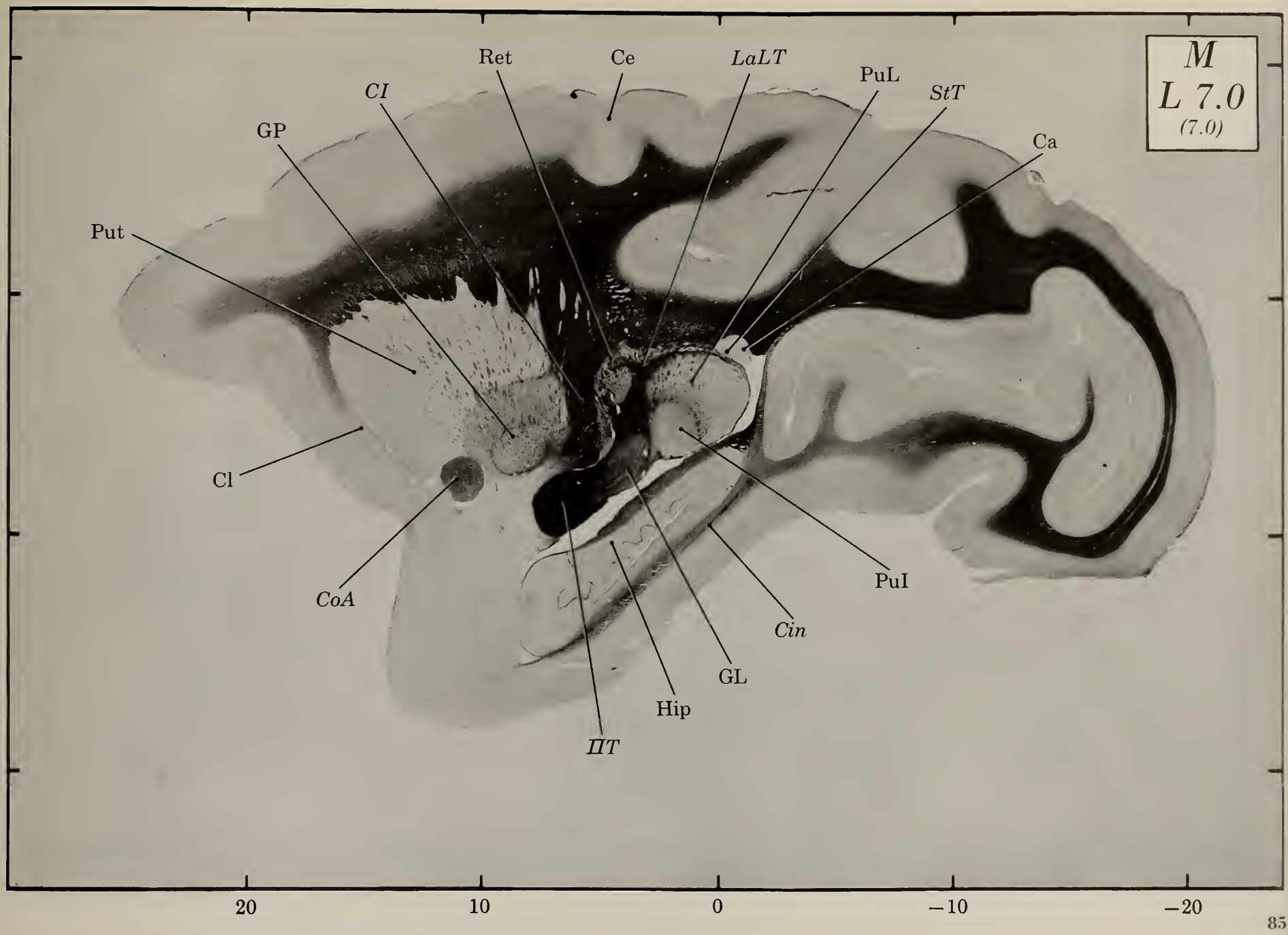
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(7.0)
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CI
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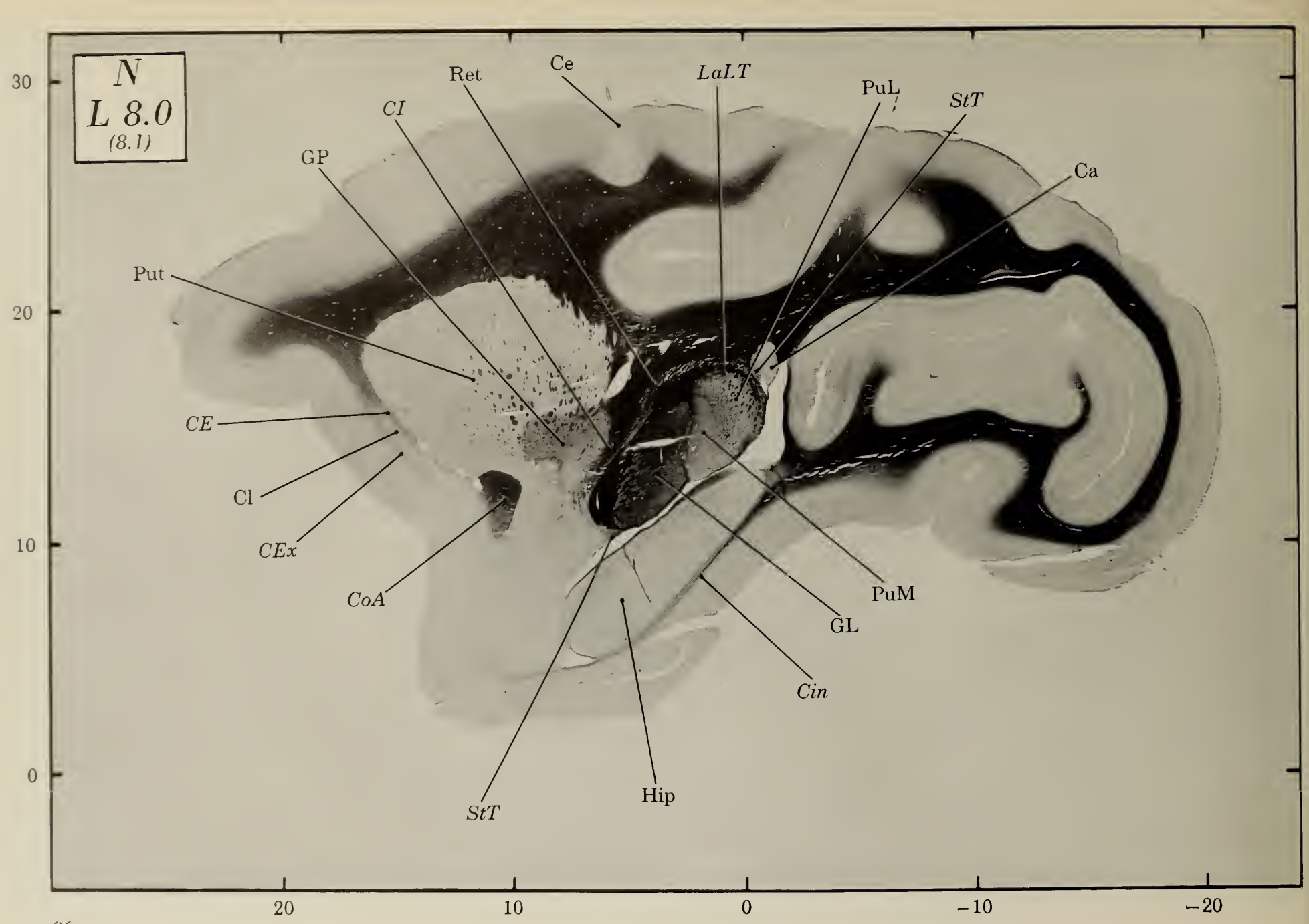
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Ret
Ce
LaLT
PuL
StT
CI
GP
Ca
Put
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GL
Cin
StT
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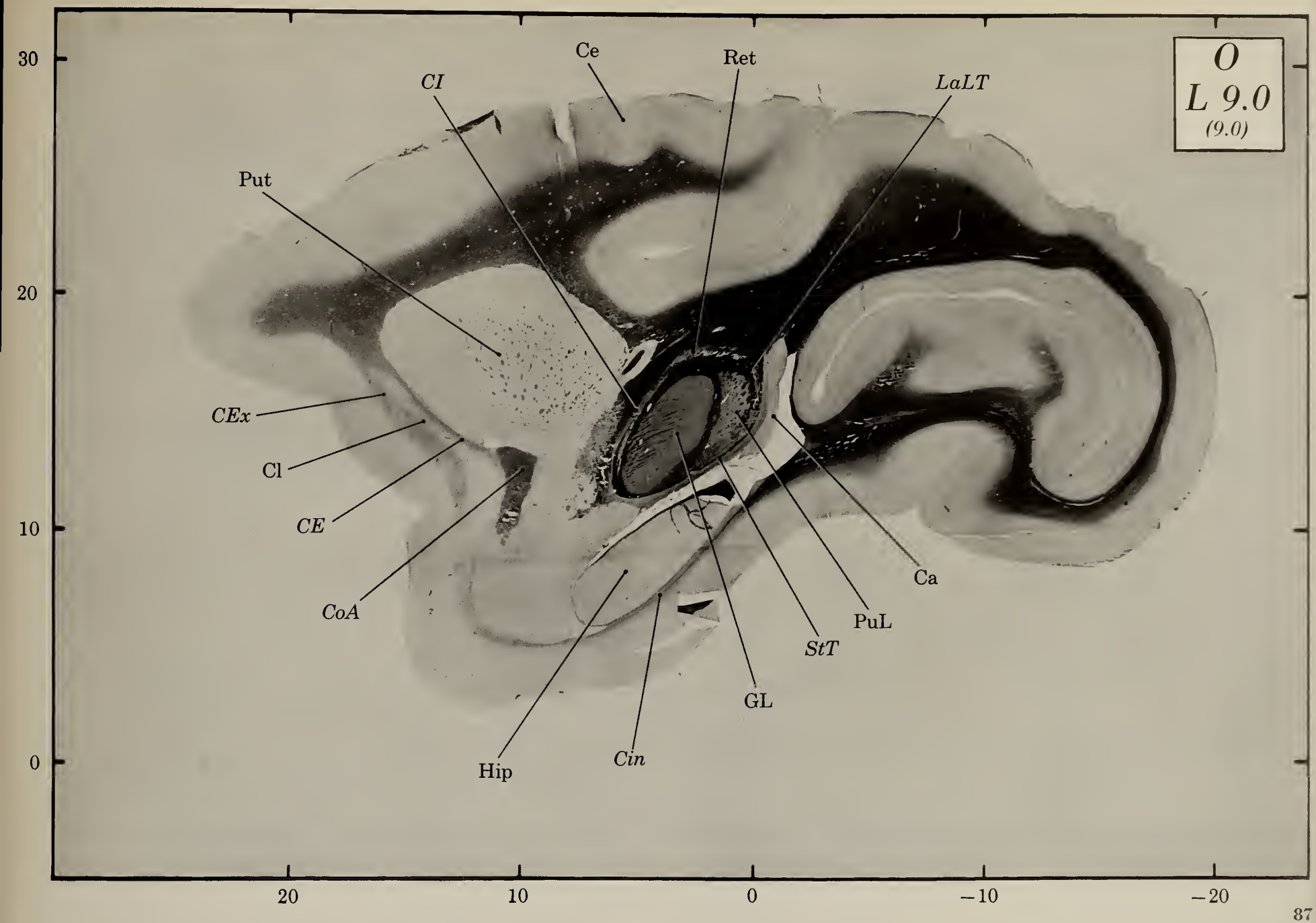
O
L 9.0
(9.0)
Ce
Ret
CI
LaLT
Put
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Cl
CE
CoA
Ca
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StT
GL
Hip
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30
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Appendix I

Purchase and Maintenance of Squirrel Monkey

It is important to find a reliable animal dealer who will regularly provide well-nourished animals with good coats. It is our experience that animals weighing appreciably less than 500 grams are either immature or sickly.

Our experimental animals are kept in cages that are 28″ long, 26″ high and 18″ wide. For purposes of climbing, cleanliness, and ease of inspection, the sides of cages are made of 1½″ stainless steel wire mesh. Usually no more than 1 or 2 animals are kept in a cage. The animal room is maintained at an average temperature of 76°. Surplus animals are kept in large runs which have access to the out of doors during seasonable months.

Exotic diets mimicing what the animals eat in the wild are not necessary and may even be deleterious. On the basis of over 10 years experience, it can be stated that the squirrel monkey can be maintained in good nutrition for periods up to several years on a standard diet of monkey chow (1). Ten to 12 soft biscuits (a biscuit weighs about 3.5 g.) appear to satisfy the daily food requirements of an average monkey. Favored foods such as grapes, bananas, and raw peanuts may be offered for purposes of training and taming.

The squirrel monkey is highly resistant to bacterial infections (1). We have had no cases of tuberculosis. A rare animal may go downhill and die with a nematode infestation. We have found that the condition of an animal's coat and its weight are the best indicators of its condition. Consequently, animals under chronic observation are weighed once a week. The addition of tetracycline (Terramycin) to the drinking water appears to be helpful if an animal develops loose stools. We do not use vermifuges and only occasionally give supplemental doses of vitamins. Antibiotics are not generally used following surgery.

Until one becomes adept at handling squirrel monkeys, a light fishnet is useful for apprehending them in the cage. Leather gloves should be worn at all times to avoid lacerations by their sharp teeth. The squirrel monkey responds well to gentle handling.

The greatest asset in the maintenance of animals is an animal caretaker who is solicitous of their needs and who by his voice, bodily movements, and methods of handling helps dispel fear.

Appendix II

Additional References

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TABLE III

Abbreviation	Title	Extent	Representative plates
I	Tractus olfactorius	SS [3]	C, E, G
IICh	Chiasma nervorum opticorum	12.5 to 10	12.5, 11.5, 10.5
IIT	Tractus opticus	9.5 to 6	9, 8, 7, 6
III	Nervus oculomotorius	6.5 to 3.5	6.5, 6, 5, 4
IV	Nervus trochlearis	0.5 to −0.5	0.5, −0.5
V	Nervus trigeminus	0.5 to −0.5	0, −0.5
VRD	Nervus trigeminus—radix descendens	SS	I, J
VRM	Nervus trigeminus—radix mesencephalica	2.5 to −0.5	1, 0
VI	Nervus abducens	1 to −0.5	0.5, 0
VII	Nervus facialis	SS	B, D, H, J
VIII	Nervus acusticus	SS	H, I, J
	Nervus abducens (see *VI*).		
	Nervus acusticus (see *VIII*).		
Alv	Alveus	9 to −0.5	8, 6, 3, 1
	Commissura anterior (see *CoA*).		
AnL	Ansa lenticularis	10 to 7	10, 9.5, 9
Ar	Fibrae arcuatae internae	SS	F, G
BCI	Brachium colliculi inferioris	3 to −0.5	2.5, 1.5, 0.5, −0.5
BCS	Brachium colliculi superioris	3.5 to 1	3, 2
Br	Brachium conjunctivum	3.5 to −0.5	2, 1, 0, −0.5
CC	Corpus callosum	15 to −0.5	15, 12, 9, 3
CE	Capsula externa	15 to 7.5	15, 13, 11.5, 8.5
CEx	Capsula extrema	15 to 7.5	14, 12.5, 10, 8
CI	Capsula interna	15 to −0.5	15, 12, 9, 6
Cin	Cingulum	15 to −0.5	15, 10, 5, 0
	Brachium colliculi inferioris (see *BCI*).		
	Brachium colliculi superioris (see *BCS*).		
CoA	Commissura anterior	12.5 to 10	12.5, 12, 11.5, 11
CoCI	Commissura colliculi inferioris	SS	A, B, C
CoCS	Commissura colliculi superioris	2.5 to 0	2, 1
CoF	Commissura fornicis (dorsal psalterium)	1 to −0.5	0.5, 0, −0.5
CoP	Commissura posterior	3.5 to 3	3.5, 3
CoS	Commissura supramammillaris	7 to 6.5	7
CS	Commissura supraoptica dorsalis—pars dorsalis (Ganser).	10	10
CSD	Commissura supraoptica dorsalis—pars ventralis (Meynert).	10 to 9.5	9.5
	Brachium conjunctivum (see *Br*).		
CSp	Tractus cortico-spinalis	5 to −0.5	2, 1, 0, −0.5
DbC	Decussatio brachii conjunctivi	4 to 1.5	3, 2.5, 1.5
DPy	Decussatio pyramidalis	SS	A, B, C
	Capsula externa (see *CE*).		
	Capsula extrema (see *CEx*).		
	Nervus facialis (see *VII*).		
	Commissura fornicis (see *CoF*).		
F	Fornix	12.5 to −0.5	12, 9, 6, 3
H1	Area tegmentalis—pars dorsalis	9 to 6	8.5, 8, 7
H2	Area tegmentalis—pars ventralis	9 to 6	8.5, 8, 7
HI	Fasciculus habenulo-interpeduncularis	6 to 4	6, 5, 4
	Capsula interna (see *CI*).		
La	Lamina medullaris incompleta (pallidi)	10 to 8	10
LaL	Lamina medullaris lateralis (pallidi)	12.5 to 6	12.5, 11.5, 10, 8
LaLT	Lamina medullaris lateralis thalami	10 to 0	9, 7.5, 3.5
LaM	Lamina medullaris medialis (pallidi)	10 to 7.5	10, 9, 8
LaMT	Lamina medullaris medialis thalami	8.5 to 3.5	8.5, 7.5, 6.5, 4.5
LeL	Lemniscus lateralis	1.5 to −0.5	0.5, 0, −0.5
LeM	Lemniscus medialis	6.5 to −0.5	3, 1.5, −0.5
LM	Fasciculus longitudinalis medialis	7 to −0.5	6, 4.5, 3, 0
MaT	Fasciculus mammillo-tegmentalis	SS	C, D
MT	Fasciculus mammillo-thalamicus	9.5 to 7.5	9.5, 9, 8.5, 8
	Lemniscus medialis (see *LeM*).		
	Pedunculus medius cerebelli (see *PMC*).		

TABLE III—Continued

Abbreviation	Title	Extent	Representative plates
	Lamina medullaris incompleta (pallidi) (see *La*).		
	Lamina medullaris lateralis (pallidi) (see *LaL*).		
	Lamina medullaris lateralis thalami (see *LaLT*).		
	Lamina medullaris medialis (pallidi) (see *LaM*).		
	Lamina medullaris medialis thalami (see *LaMT*).		
	Stria medullaris thalami (see *StM*).		
	Nervus oculomotorius (see *III*).		
	Stria olfactoria lateralis (see *StO*).		
	Radiatio olfactoria profunda (see *RaO*).		
Ol	Fasciculus olfactorius (Zuckerkandl)*	14 to 13	14, 13.5, 13
OlF	Fasciculus olfactorius fornicis (fornix longus).	13 to 11.5	12.5, 12
OlH	Fasciculus olfactorius hippocampi (diagonal band of Broca).*	13 to 11	13, 12, 11
	Tractus olfactorius (see *I*).		
	Chiasma nervorum opticorum (see *IICh*).		
	Tractus opticus (see *IIT*).		
P	Pes pedunculi	8 to 4	7.5, 6.5, 5.5, 4.5
PMC	Pedunculus medius cerebelli (brachium pontis).	6 to −0.5	2, 1, 0, −0.5
PVT	Pedunculus ventralis thalami	10.5 to 9	10.5, 10, 9.5
	Commissura posterior (see *CoP*).		
	Decussatio pyramidalis (see *DPy*).		
RaO	Radiatio olfactoria profunda	15 to 11.5	15, 14, 13, 12
Res	Corpus restiforme (pedunculus inferior cerebelli).	SS	I, J
Sol	Fasciculus solitarius	SS	E, F
Spt	Tractus spino-thalamicus	SS	I
SS	Stratum subcallosum (Muratoff)	15 to −0.5	15, 13, 11, 9
SSP	Stratum superficiale pontis	6 to 1.5	5.5, 5, 4
StM	Stria medullaris thalami	11.5 to 3.5	10.5, 9.5, 7.5, 5.5
StO	Stria olfactoria lateralis	15 to 13	15, 14.5, 13.5
StT	Stria terminalis (stria semicircularis)*(10)	11.5 to 0	11.5, 10, 8.5, 5.5
	Stratum subcallosum (see *SS*).		
	Commissura supramammillaris (see *CoS*).		
	Commissura supraoptica dorsalis—pars dorsalis (see *CS*).		
	Commissura supraoptica dorsalis—pars ventralis (see *CSD*).		
	Area tegmentalis—pars dorsalis (see *H1*).		
	Area tegmentalis—pars ventralis (see *H2*).		
TeC	Tractus tegmentalis centralis	5 to −0.5	4, 3, 2, 0
TeM	Fasciculus telencephalicus medialis (median forebrain bundle).	12.5 to 7	12, 11, 10, 9
	Stria terminalis (see *StT*).		
Trz	Corpus trapezoides	1 to −0.5	1, 0.5
	Nervus trigeminus (see *V*).		
	Nervus trigeminus—radix descendens (see *VRD*).		
	Nervus trigeminus—radix mesencephalica (see *VRM*).		
	Nervus trochlearis (see *IV*).		
Un	Fasciculus uncinatus	15 to 7	14, 12, 11, 10
	Pedunculus ventralis thalami (see *PVT*).		

Footnote 3:

SS in tables III and IV refers to the sagittal sections. The structures having this designation have been labeled only in the sagittal series of plates; other structures may be labeled in both frontal and sagittal plates.

TABLE IV

Abbreviation	Title	Extent	Representative plates
IIIN	Nucleus nervi oculomotorii	5 to 2	4.5, 4, 3.5, 3
IVN	Nucleus nervi trochlearis	1.5 to 0.5	1.5, 1, 0.5
VM	Nucleus motorius nervi trigemini	−0.5	−0.5
VS	Sulcus trigeminalis pontis	1.5 to −0.5	0.5, 0, −0.5
VIN	Nucleus nervi abducentis	SS [3]	D, E
VIIN	Nucleus nervi facialis	SS	H
A	Nucleus accumbens septi	15 to 12.5	15, 14, 13
AB	Nucleus amygdalae basalis	11.5 to 8.5	11, 10.5, 10, 9
ABA	Nucleus amygdalae basalis accessorius	11.5 to 9	11, 10.5, 10, 9.5
AC	Nucleus amygdalae centralis	11.5 to 9	11, 10.5, 10, 9.5
ACo	Nucleus amygdalae corticalis	12.5 to 8.5	12, 11, 10, 9
AL	Nucleus amygdalae lateralis	12 to 7.5	12, 11, 10
AM	Nucleus amygdalae medialis	11.5 to 7.5	10, 9.5
AmA	Area amygdaliformis anterior	12.5 to 11.5	12.5, 12
AnD	Nucleus antero-dorsalis thalami	9 to 6.5	8, 7.5
AnM	Nucleus antero-medialis thalami	9.5 to 8.5	9.5, 9
AnV	Nucleus antero-ventralis thalami	10 to 6.5	9.5, 9, 8, 7.5
Aq	Anulus aquaeductus	3.5 to −0.5	3.5, 2.5, 1.5, 0.5
B	Nucleus basalis	12.5 to 6.5	12, 11, 10, 9
	Locus caeruleus (see LoC).		
C	Fissura calcarina	SS	E, G, J
Ca	Nucleus caudatus	15 to −0.5	15, 11, 7, 3
Ce	Sulcus centralis (Rolandi)* (10)	6	6
	Substantia centralis grisea (see SubC).		
CeL	Nucleus centralis lateralis,* (8)	6 to 3.5	6, 5, 4
Cen	Nucleus centralis superior (Bechterew)	4 to 0.5	2.5, 2, 1.5, 1
Cent	Nucleus centri mediani thalami	6.5 to 4	6, 5.5, 5, 4
Cer	Hemisphaerium cerebelli	−0.5	−0.5
CerL	Fissura cerebri lateralis (Sylvius)	15 to −0.5	13, 10, 8.5, 6.5
Ci	Gyrus cinguli	15 to −0.5	15, 10, 5, 0
Cir	Sulcus circularis insulae (limitans insulae)	13.5	13.5
Cl	Claustrum	15 to 7.5	15, 13.5, 12, 9
ColI	Colliculus inferior	0.5 to −0.5	0, −0.5
ColS	Colliculus superior	2.5 to −0.5	2.5, 1.5, 0.5, −0.5
D	Nucleus Darkschewitsch (commissurae posterioris)*	6 to 4	5.5, 5, 4.5
Den	Gyrus dentatus	SS	L
Dent	Nucleus dentatus cerebelli	SS	I, J
DT	Nucleus dorsalis tegmenti (Gudden)	−0.5	−0.5
EW	Nucleus Edinger-Westphal (parvocellularis nervi oculomotorii)*	6 to 4.5	5.5, 5
FaC	Nucleus fasciculi cuneati (Burdach)	SS	F, G, H.
FaG	Nucleus fasciculi gracilis (Goll)	SS	B, D, E.
Fas	Nucleus fastigii cerebelli	SS	B, C, D.
GL	Corpus geniculatum laterale	5.5 to 2	5, 4, 3, 2
GM	Corpus geniculatum mediale	4 to 2	3.5, 3, 2.5
GP	Globus pallidus	12.5 to 6	12.5, 10, 8, 6.5
H	Area tegmentalis (Forel)	7 to 6	6.5
Ha	Nucleus habenularis	SS	B, C, D
HaL	Nucleus habenularis—pars lateralis	4.5 to 3	4, 3.5, 3
HaM	Nucleus habenularis—pars medialis	4.5 to 3	4, 3.5, 3
Hip	Hippocampus (cornu ammonis)	8.5 to −0.5	8, 2, −0.5
HyA	Area hypothalamica anterior	12 to 10	12, 11.5, 11
HyD	Area hypothalamica dorsalis	10 to 7.5	9.5, 9, 8
HyL	Area hypothalamica lateralis	11 to 7.5	10, 9, 8
HyP	Area hypothalamica posterior	8 to 7.5	7.5
HyV	Nucleus hypothalamicus ventromedialis	10 to 8.5	9.5, 9
	Zona incerta (see ZI).		
I	Insula	13.5 to 7.5	13, 12, 11, 10
In	Nucleus interpeduncularis	6 to 3.5	5.5, 5, 4.5, 4
Inp	Nucleus interpositus (cerebelli)	SS	H
Int	Nucleus interstitialis (Cajal)	6 to 4.5	6, 5.5, 5, 4.5

TABLE IV—Continued

Abbreviation	Title	Extent	Representative plates
Is	Islands of Calleja	14 to 11	13.5
LaD	Nucleus lateralis dorsalis (disseminati dorsales thalami)* (8).	7 to 4	6.5, 6, 5.5, 5
LaP	Nucleus lateralis posterior thalami	6 to 3	6, 5.5, 5, 4.5
LaV	Nucleus lateralis ventralis thalami	9.5 to 6.5	8.5, 8, 7, 6.5
Le	Nucleus lemnisci lateralis (dorsalis lemnisci lateralis)* (10).	1 to −0.5	1, 0.5, 0, −0.5
LoC	Locus caeruleus	−0.5	−0.5
M	Corpus mammillare	7.5 to 7	7.5, 7
MD	Nucleus medialis dorsalis thalami	8.5 to 3.5	8, 7, 6, 4
	Substantia nigra (see SubN).		
OcT	Fissura occipito-temporalis	5 to −0.5	4.5, 3.5, 2.5, 0.5
Olf	Area olfactoria (tuberculum olfactorium)	14.5 to 13	14, 13.5, 13
OlI	Nucleus olivaris inferior	SS	E, F, G
OlS	Nucleus olivaris superior accessorius	0 to −0.5	0, −0.5
Pac	Nucleus paracentralis* (8)	9.5 to 6	9, 8, 7
Paf	Nuclei parafasciculares thalami	7 to 4	6.5, 5.5, 4.5
Pat	Nuclei parataeniales thalami	9 to 5	9, 7.5, 5.5
Pav	Nucleus paraventricularis hypothalami	11.5 to 9.5	11, 10.5, 10
PavT	Nucleus paraventricularis thalami* (10)	11 to 5	11, 10.5, 10
Per	Nucleus peripeduncularis dorsalis	5.5 to 3	5, 4, 3
Pin	Corpus pineale	2.5 to 2	2.5, 2
Po	Nucleus pontis	5.5 to 1	5, 4, 3, 2
Pr	Nucleus praegeniculatus	5.5 to 5	5.5, 5
Pro	Area praeoptica	12.5 to 12	12.5, 12
Prt	Area praetectalis	3.5 to 3	3.5, 3
PuI	Nucleus pulvinaris inferior thalami	3.5 to 2	3, 2.5, 2
PuL	Nucleus pulvinaris lateralis thalami	3.5 to 0	3, 2, 1
PuM	Nucleus pulvinaris medialis thalami	3.5 to 0	3, 2, 1
PuO	Nucleus pulvinaris oralis thalami* (8)	4.5 to 3	4, 3.5, 3
Put	Putamen	15 to 4	15, 12, 9, 6
R	Gyrus rectus	15 to 14.5	15
Re	Formatio reticularis	4.5 to −0.5	3, 2, 1, 0
ReP	Nucleus reticularis tegmenti pontis (pterygoideus).	3.5 to 0.5	3, 2, 1
Ret	Nucleus reticularis thalami	11 to 0	11, 9, 6, 3
Rub	Nucleus ruber tegmenti	6 to 3.5	5.5, 5, 4.5, 4
SL	Area septalis—pars lateralis*	15 to 12	14, 13, 12
SM	Area septalis—pars medialis*	15 to 12	14, 13, 12.5
SO	Nucleus striae olfactoriae lateralis	13 to 12	12.5
ST	Nucleus striae terminalis*	12.5 to 11	12, 11.5, 11
SubC	Substantia centralis grisea	SS	A, B
SubN	Substantia nigra	7.5 to 3	7.5, 6, 5, 4
Subt	Corpus subthalamicum	8 to 6.5	7.5, 7, 6.5
Sug	Nucleus subgeniculatus	3.5 to 3	3.5, 3
Suo	Nucleus supraopticus hypothalami	12 to 10	12, 11
Sut	Nucleus supratrochlearis substantiae griseae	0.5 to 0	0
	Area tegmentalis (see H).		
T	Fissura temporalis superior	11.5 to −0.5	11, 9.5, 4.5, 0.5
Tri	Area triangularis (Wernicke)	5.5 to 4	5, 4.5
	Sulcus trigeminalis pontis (see VS).		
Tu	Pars tuberalis hypothalami	9.5 to 7.5	9.5, 9, 8
U	Gyrus uncinatus	10 to 7.5	9.5, 9, 8
VA	Nucleus ventralis anterior thalami	10.5 to 9	10.5, 10, 9.5
VPL	Nucleus ventralis postero-lateralis thalami	8.5 to 4	7, 6, 5, 4.5
VPM	Nucleus ventralis postero-medialis thalami	7.5 to 5	6.5, 6, 5.5, 5
ZI	Zona incerta	9.5 to 6	8, 7.5, 7, 6.5

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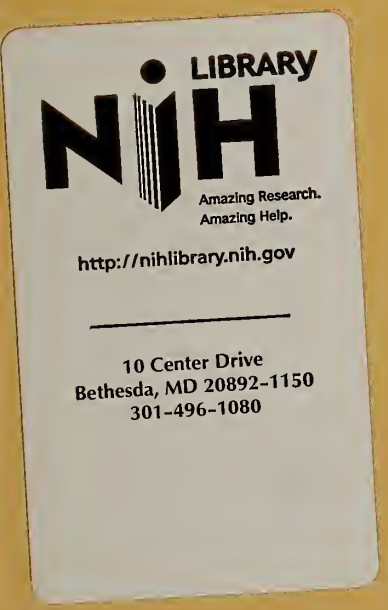

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